National Park Service
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Natural Resource Stewardship and Science

Resource Management and Operations in Southwest South Dakota

Climate Change Scenario Planning Workshop Summary

January 20-21, 2016, Rapid City, SD

Natural Resource Report NPS/NRSS/NRR—2016/1289









ON THE COVER

Workshop participants worked collaboratively to examine possible scenarios under ongoing climate change to help inform future management and planning decisions regarding American bison (top left), the badlands/grassland landscape (top right), prairie dogs (center), paleontological resources (bottom left), black-footed ferrets (bottom right), and other topics. NPS photos.

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National Park Service
Natural Resource Stewardship and Science
Fort Collins, Colorado

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Contents

Figures

Figures (continued)

Page

Tables

Page

Appendices

Page

Abstract

The *Scaling Climate Change Adaptation in the Northern Great Plains through Regional Climate Summaries and Local Qualitative-Quantitative Scenario Planning Workshops* project synthesizes climate data into 3-5 distinct but plausible climate summaries for the northern Great Plains region; crafts quantitative summaries of these climate futures for two focal areas; and applies these local summaries by developing climate-resource-management scenarios through participatory workshops and, where possible, simulation models. The two focal areas are central North Dakota and southwest South Dakota (Figure 1). The primary objective of this project is to help resource managers and scientists in a focal area use scenario planning to make management and planning decisions based on assessments of critical future uncertainties.

This report summarizes project work for public and tribal lands in the southwest South Dakota grasslands focal area, with an emphasis on Badlands National Park and Buffalo Gap National Grassland. The report explains scenario planning as an adaptation tool in general, then describes how it was applied to the focal area in three phases. Priority resource management and climate uncertainties were identified in the orientation phase. Local climate summaries for relevant, divergent, and challenging climate scenarios were developed in the second phase. In the final phase, a two-day scenario planning workshop held January 20-21, 2016 in Rapid City, South Dakota, featured scenario development and implications, testing management decisions, and methods for operationalizing scenario planning outcomes.

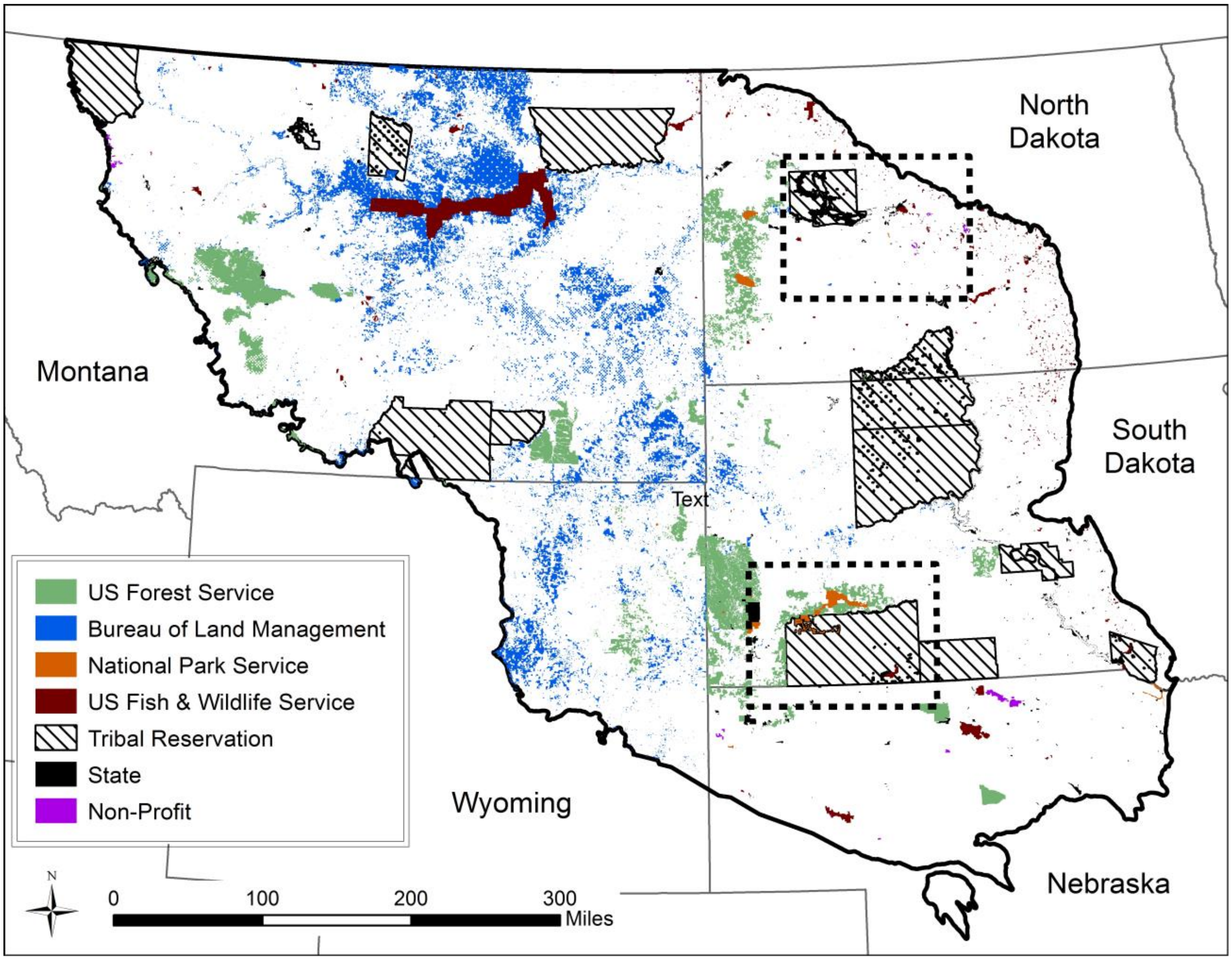


Figure 1. Map of Northern Great Plains area (solid black outline) included in the Scaling Climate Change Adaptation in the Northern Great Plains through Regional Climate Summaries and Local Qualitative-Quantitative Scenario Planning Workshops project. Two focal areas for the project (central North Dakota and southwest South Dakota) are shown in black rectangles.

Acknowledgments

We thank the workshop participants for their insights, participation, and tremendous energy. Funding for this project was provided by the Department of Interior North Central Climate Science Center, and in-kind contributions were made by the National Park Service Climate Change Response Program, National Oceanic and Atmospheric Administration/Earth Sciences Research Laboratory Physical Sciences Division, U.S. Geological Survey Northern Prairie Wildlife Research Center, and Wildlife Conservation Society. We thank J. Star and H. Hartmann for materials and ideas and M. Talbert for assistance in processing climate data. We acknowledge the modeling groups, the Program for Climate Model Diagnosis and Intercomparison (PCMDI) and the WCRP's Working Group on Coupled Modelling (WGCM) for their roles in making available the WCRP CMIP5 multi-model dataset, and the "Downscaled CMIP3 and CMIP5 Climate and Hydrology Projections" archive. Support of the WCRP dataset is provided by the Office of Science, U.S. Department of Energy.

Introduction

Uncertainties are inherent to planning around complex environmental issues (Gregory et al. 2012) and are addressed by resource managers in a variety of ways. In recent years, awareness of the largely uncontrollable uncertainty surrounding climate change, not knowing precisely when, where, and how climate change effects will unfold, has had an increased influence in decision-making (Peterson et al. 2003, Rowland et al. 2014). Understanding and working with uncertainties, especially those arising from external drivers like climate change, will ultimately empower decision-makers to take action now while planning for the future.

Scenario planning is a flexible tool that is useful for understanding potential climate change implications and uncertainties in a way that is relevant to resource and landscape management. Scenario planning facilitates decision-making by providing a structured process for building and thinking about a range of possible futures that managers may face, in order to consider not just what is likely, but also what is plausible, relevant, and highly consequential (Figure 2; NPS 2013). This collaborative approach uses science at management-relevant scales and can include social and political factors affecting decisions. The process encourages long-term science-management partnerships by providing a setting to consider the breadth of uncertainty around climate impacts and their interaction with other stressors, and the opportunity to explore a range of innovative responses. Using scenarios as part of planning can offer benefits in the form of (1) an increased understanding of key uncertainties facing resource management and operations, (2) the incorporation of alternative perspectives into resource management planning, and (3) an improved capacity for adaptive management to achieve desired conditions.

A crucial part of climate change scenario planning is assessing and understanding relevant climate uncertainties, which are expressed as the range of results from projections for a variety of climate variables. Although this range of projected futures provides resource managers a realistic representation of the uncertainties about future climate, the volume of information can be daunting for managers trying to incorporate climate change into their planning. Science partners can help managers winnow down plausible climate futures by (1) asking and determining which climate variables and aspects of those variables are critical forces in shaping focal resources, (2) evaluating uncertainty in these variables from their ranges represented in climate projections, and (3) synthesizing coherent climate summaries that cover a plausible range of futures for the key variables at the relevant spatial scale.

> *"Scenarios are stories about the ways that the world might turn out tomorrow…that can help us recognize and adapt to changing aspects of our current environment."*
>
> -Peter Schwartz,
> *The Art of the Long View*

Climate summaries are made relevant to management by comparing climate projections to historical climate trends and weather events, then determining the consequences of plausible future climates for focal resources in the context of other stressors. NPS has developed and refined a qualitative scenario planning approach focused on expert opinion and synthesis of pre-existing science (NPS 2013). Managers are increasingly interested in using scenario planning for specific resource planning and actions; quantitative simulations may better assess complex resource dynamics and potential effects of management actions. The scenarios developed here for central North Dakota include both quantitative model output and expert opinion (Rowland et al. 2014).

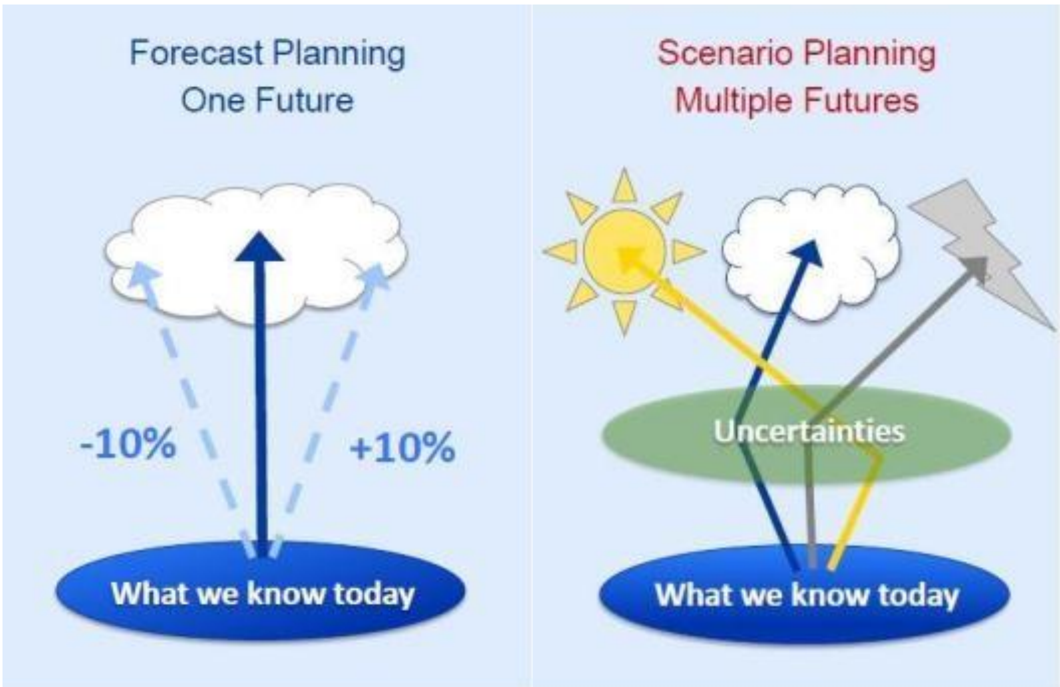


Figure 2. Scenarios offer a range of plausible future environments (right panel) – not predictions (left panel) – and provide a framework to support decisions under conditions that are uncertain and uncontrollable. Graphics from Global Business Network (GBN).

Project Timeline and Process

To provide local-scale adaptation support, we focused our efforts on the plains of southwest South Dakota in an area where land is managed by federal and tribal agencies, non-governmental organizations, and private landowners (Figure 3). During an orientation phone call on April 30, 2015 we introduced the project to key management partners and identified additional information sources and stakeholders. To create relevant scenarios and focus the workshop on pertinent management concerns, we then met with a broader group of managers and scientists in a project orientation meeting on August 24, 2015 at Badlands National Park. The scenario planning workshop took place at Outdoor Campus West on January 20-21, 2016 in Rapid City, SD.

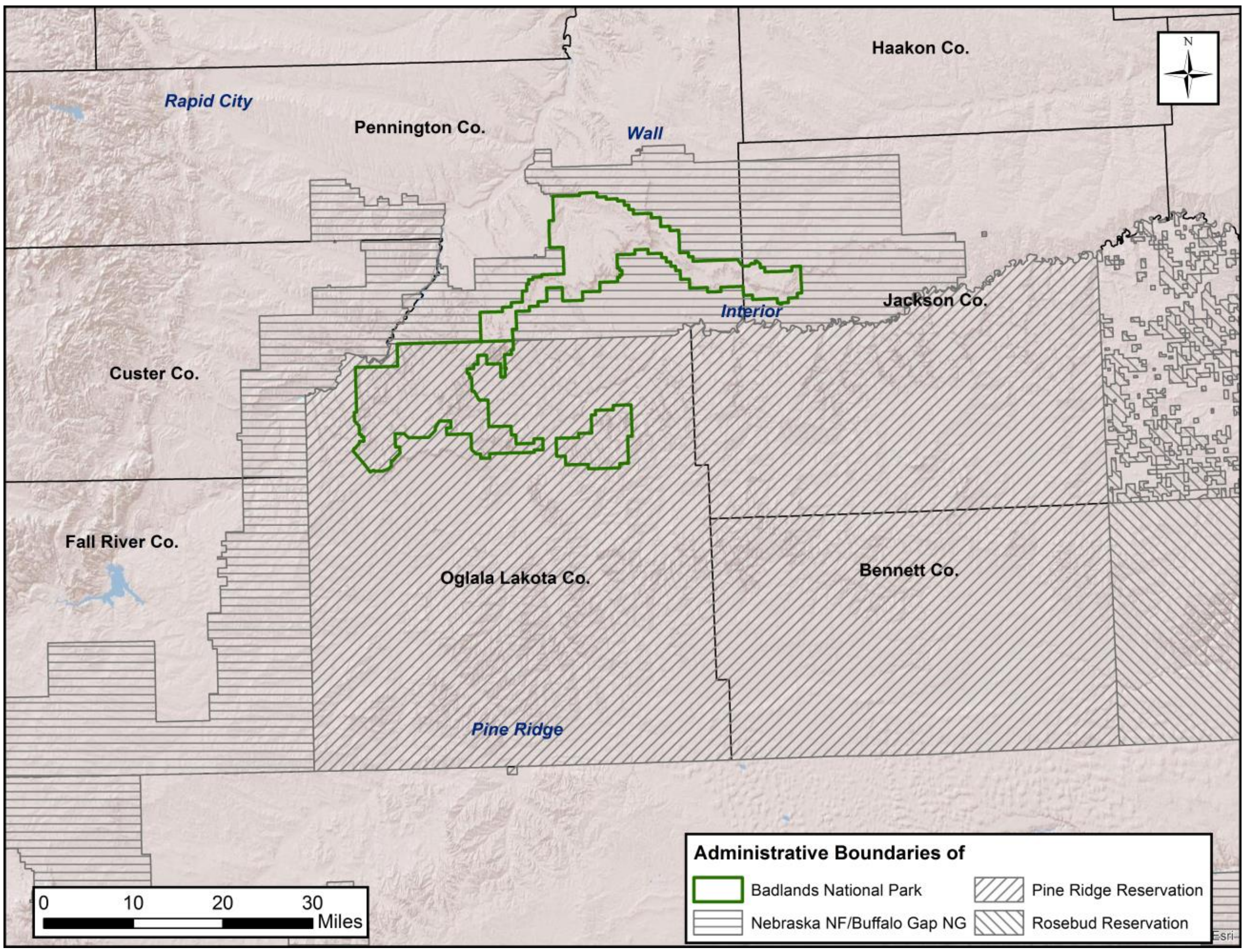


Figure 3. Southwest South Dakota project focal area with counties ("Co.") and municipalities (in italics) for reference.

Management Concerns and Focal Issues

General management-related concerns expressed by managers during the orientation phase included a wide range of topics. Extreme precipitation events and their erosion-related effects on paleontological resources and infrastructure were one concern. Drought was also a concern due to its effects on forage availability, longer-term grassland species composition, and indirect effects on wildlife such as prairie dogs, black-footed ferrets, and bison (Amberg et al. 2012). Several other factors that affect the character and viability of grasslands, livestock, and wildlife on this landscape were discussed, including invasive species, fire, and range management practices (e.g., stocking rates and the development of supplemental water sources). We also briefly discussed past and potential future socio-political changes.

Orientation-phase participants identified three broad focal issues to address in the scenario planning workshop: (1) archaeological and paleontological resources; (2) grassland vegetation composition and productivity, bison and cattle grazing, and wildlife, particularly prairie dogs and black-footed ferrets; and (3) park operations, including facilities and infrastructure.

Weather and Climate Effects on Erosion, Grasslands, and Grazing

The scenario planning workshop included science presentations on climate context, key topics, and management issues. Scott Rudge, National Weather Service, presented on the historical climate of the focal area; Larry Stetler, South Dakota School of Mines and Technology, presented on erosion processes in paleontological sites at Badlands National Park; Amy Symstad, U.S. Geological Survey, presented on climate effects on grassland ecology; and Justin Derner, USDA Northern Plains Regional Climate Hub, presented on climate variability’s effects on livestock grazing and economics. Highlights from these presentations are summarized here.

The climate of southwest South Dakota is categorized as cold semiarid steppe, with annual precipitation less than that of potential evapotranspiration, and characterized by hot and fairly dry summers, cold and dry winters, spring-early summer precipitation peaks, and strong diurnal and seasonal temperature variability (Figure 4). Interannual precipitation variability is also high.

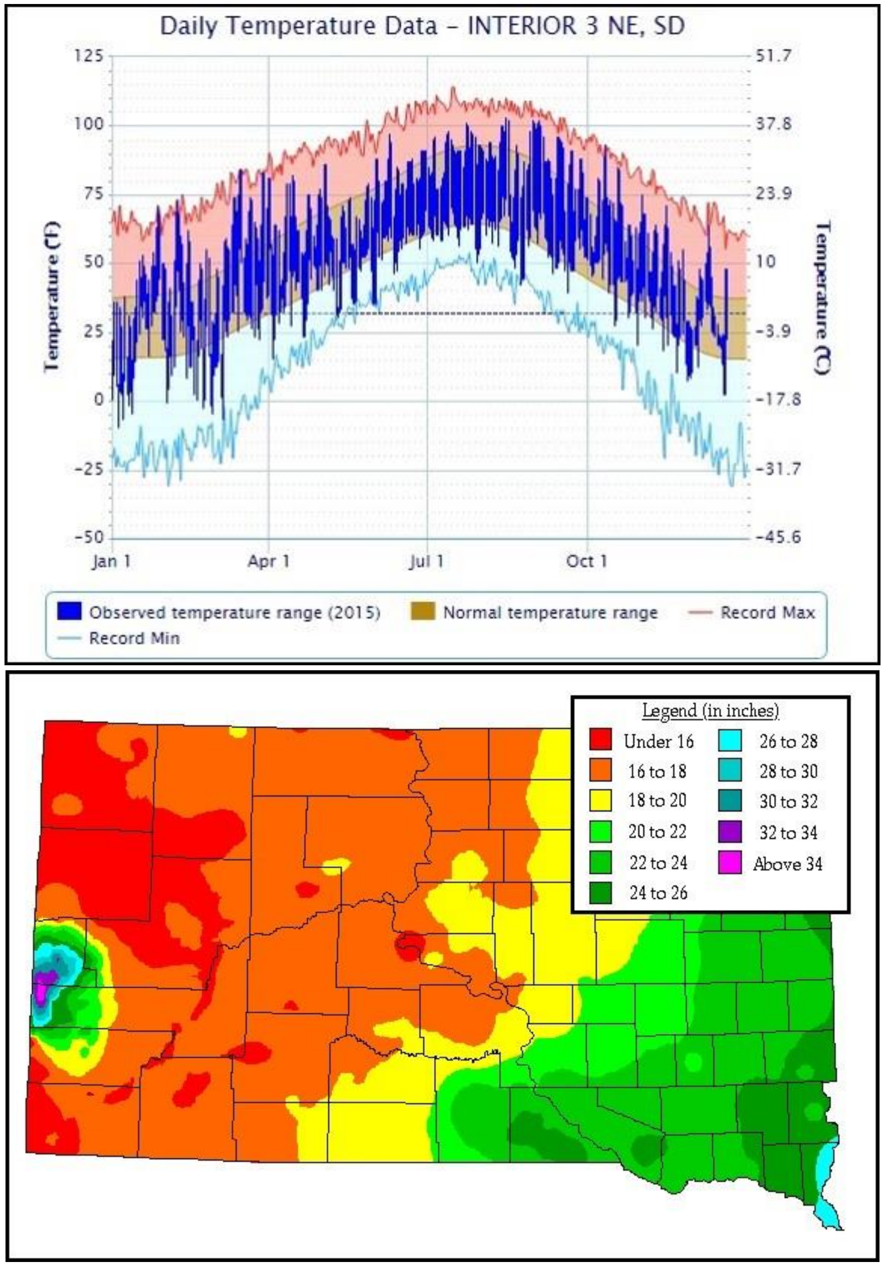


Figure 4. Historical temperature and precipitation patterns for the focal area. (Top) Normal and record temperatures, overlain by observed 2015 temperatures, for the weather station at Interior, South Dakota. (Bottom) Average annual precipitation for the whole state of South Dakota. Figures from S. Rudge.

Erosion is a central feature of the Badlands and is in part driven by climate, especially heavy precipitation events (Stetler 2013). Changes in wet/dry cycles and erosion rates will affect the weathering, deterioration and loss of archeological and paleontological resources (Figure 5).

Figure 5. Fossil tortoise shell in Badlands National Park. Increased erosion rates, as may occur with more intense rain events in the future, will accelerate the exposure, weathering, and destruction of paleontological resources. Image from L. Stetler.

Native grasslands in the region are influenced by myriad biotic and abiotic factors, including climate, grazing animals, fire, and non-native species (Figure 6). All of the boxes and arrows on the Figure 6 diagram are influenced by various aspects of climate – precipitation, temperature, wind, and the timing and magnitude of meteorological and climate events. Interactions among climate, soils, and management actions including grazing, fire, cutting, and seeding influence the specific plant composition of grasslands (Figure 7). Livestock production in the region is strongly influenced by grassland composition and productivity, and thus by precipitation (Figure 8). Appropriate stocking rates and economic returns vary from year to year with grassland productivity. Enhanced accuracy of seasonal precipitation and temperature forecasts could inform stocking rates and other management actions and increase economic return.

Based on historical weather station data (1956-2015) from Interior, SD (station - GHCND:USC00394184), annual average temperature ranged from 45.4 to 56.1 °F, with a mean of 50.5 °F, and annual precipitation varied from 10.6 to 27.1 inches, with a mean of 17.0 inches (Figure 9). Over this historical period, annual temperature exhibited a non-significant (p-value = 0.17) increasing linear trend and annual precipitation showed a significant (p-value = 0.0003) increasing linear trend, but substantial interannual variability.

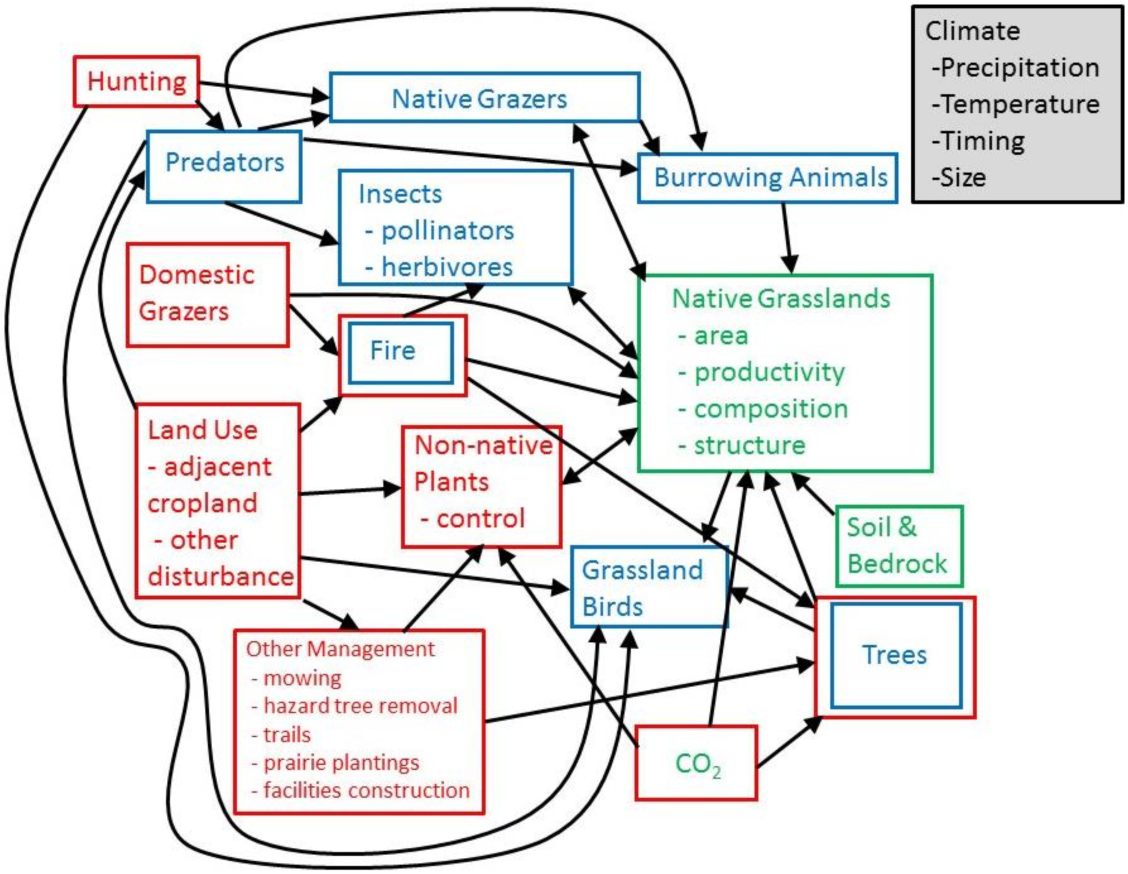


Figure 6. Conceptual model of grassland ecosystems in southwest South Dakota, showing the interconnected system components. Green items are primary producers or the resources on which they depend; blue items and boxes are natural features that influence native grasslands, and red items or boxes indicate anthropogenic factors or influences in the environment. All aspects of climate (gray box) influence ecosystem components and interactions.

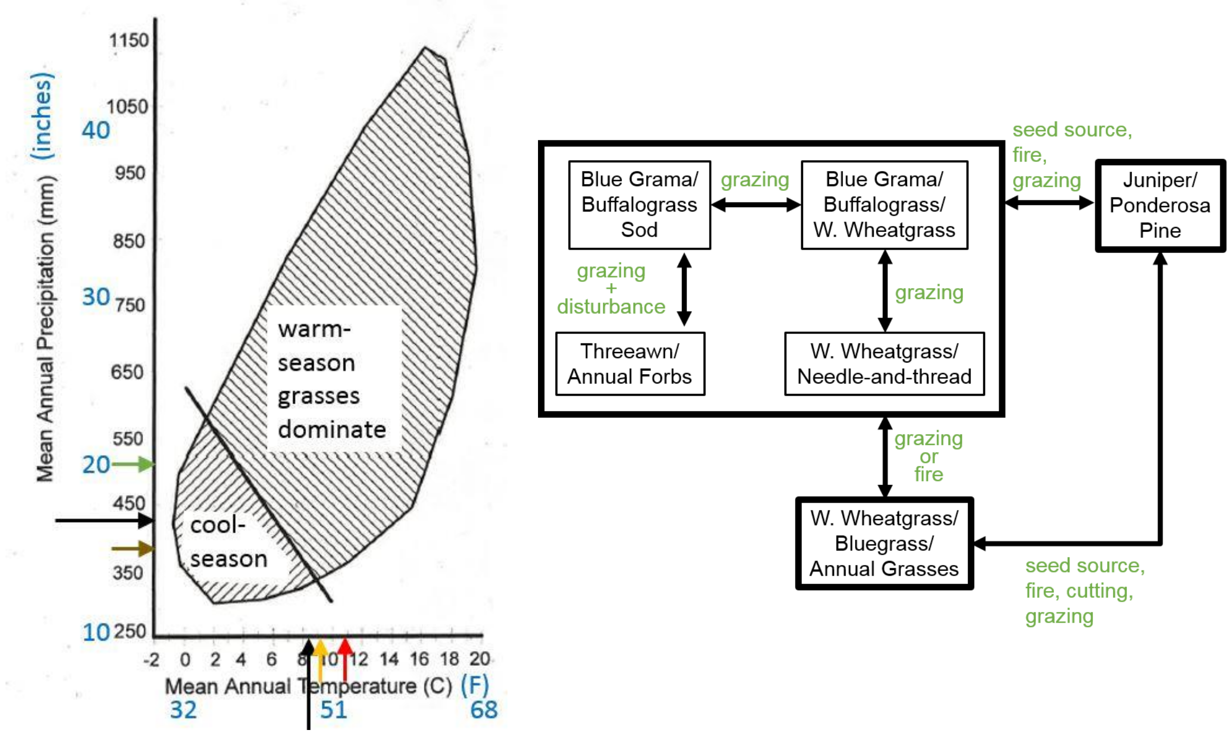


Figure 7. Influence of long-term climate and medium-term management on grassland vegetation composition. Left: General relationship between North American grassland composition and mean annual temperature and precipitation. Black arrows indicate historical (1950-1999) conditions and colored arrows indicate the range of conditions in 2020-2050 climate projections considered for the workshop. Figure modified from Lauenroth et al. 1999. Right: Conceptual state-and-transition model of vegetation typical of the focal area depicting the ways in which grassland composition is affected by management actions.

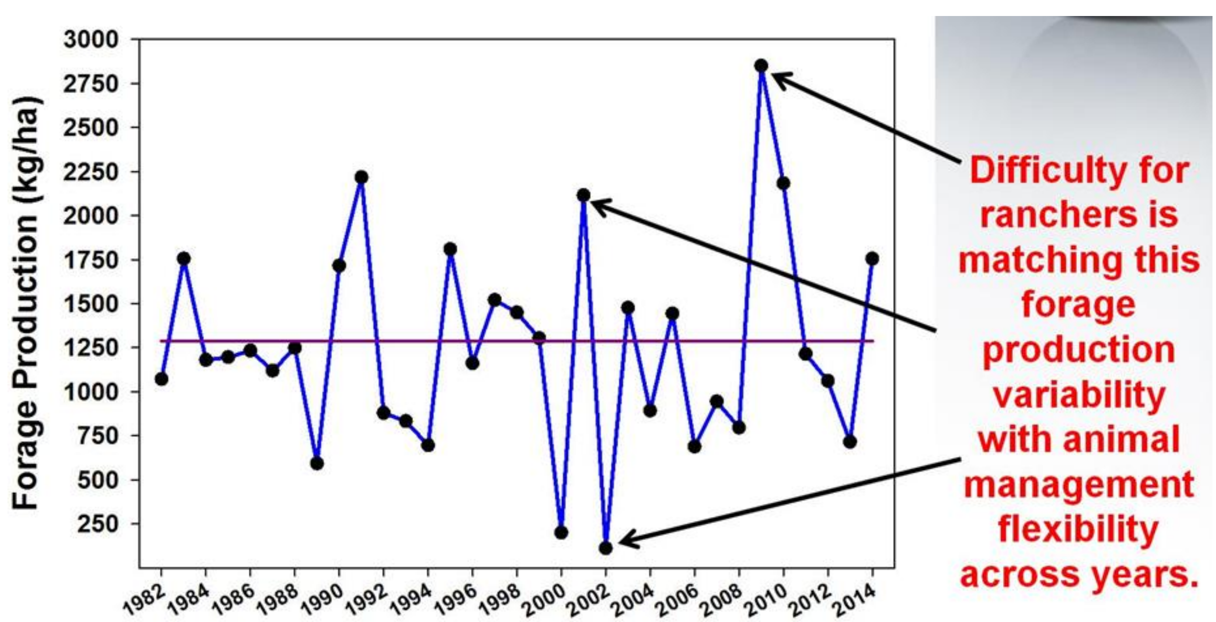


Figure 8. Forage production varies strongly from year to year in response to vegetation responses to moisture availability. Figure from J. Derner.

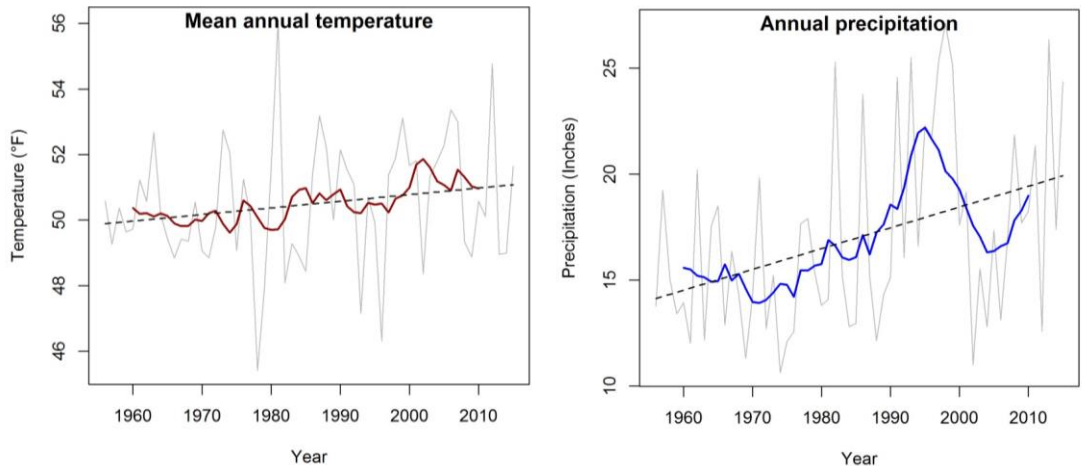


Figure 9. Historical (1956-2015) annual average temperature (left) and total precipitation (right) from the Interior, SD, weather station (GHCND:USC00394184). Light gray lines show annual values and bold colored lines are 10-year running averages. Dashed lines are the simple linear regression trend lines (temperature p-value = 0.17, precipitation p-value = 0.0003).

Average future climate projections for the Northern Great Plains indicate continued warming and potentially more precipitation (Figure 10; Kunkel et al. 2013). However, projections vary among individual models; climate projections for 2020-2050 summarized for the workshop span a range of warming in annual temperature from +1.7 °F to +5.9 °F, and a range of annual precipitation change from -13% to +20% (Figure 11). Additionally, seasonal shifts in precipitation patterns (type, frequency, and intensity) and growing season conditions (onset, duration, and soil moisture levels) vary among climate models. Given the range of future projections, planning for a single future is highly unlikely to prepare a manager for what will actually transpire in the coming decades.

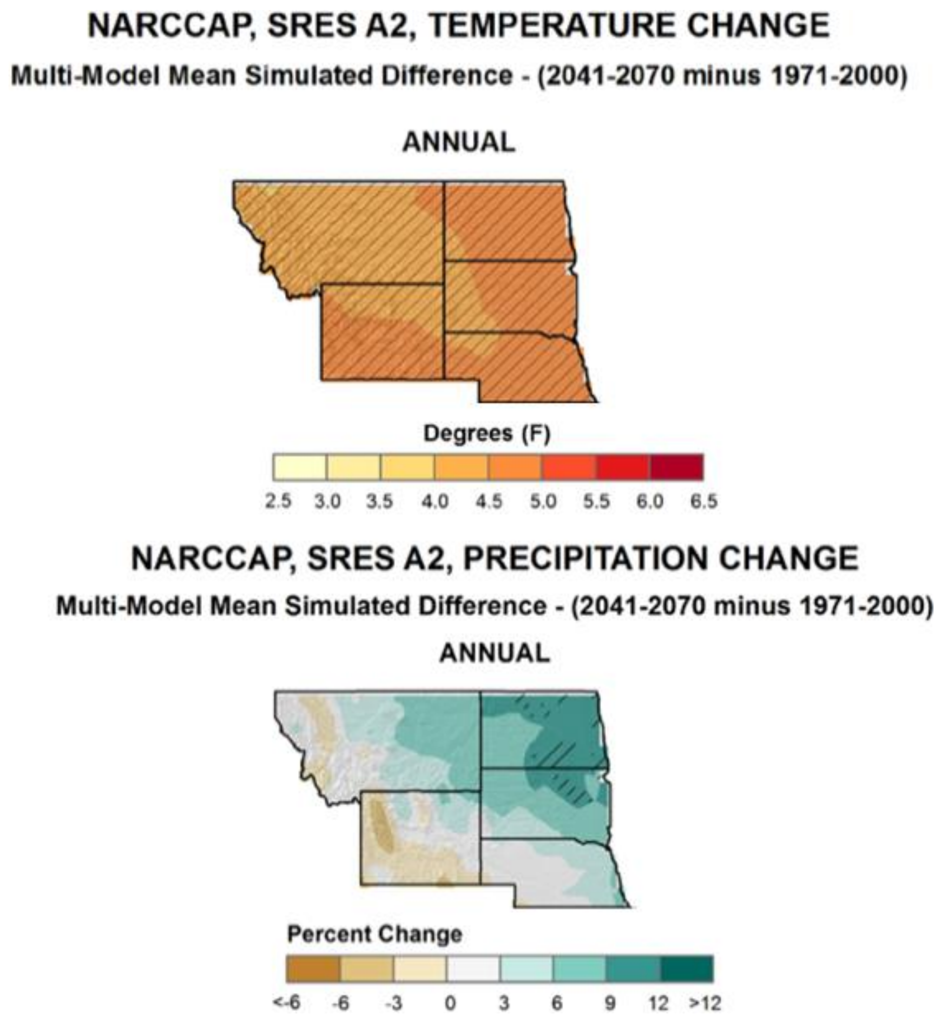


Figure 10. Projected multi-model mean annual temperature and precipitation change for the Northern Great Plains from 11 downscaled global climate model SRES A2 greenhouse gas emissions scenario projections. Color with hatching indicates >50% of the 11 models show a statistically significant change and >67% agree on the direction of change. Modified from figures 14 (top) and 25 (bottom) from Kunkel et al. (2013).

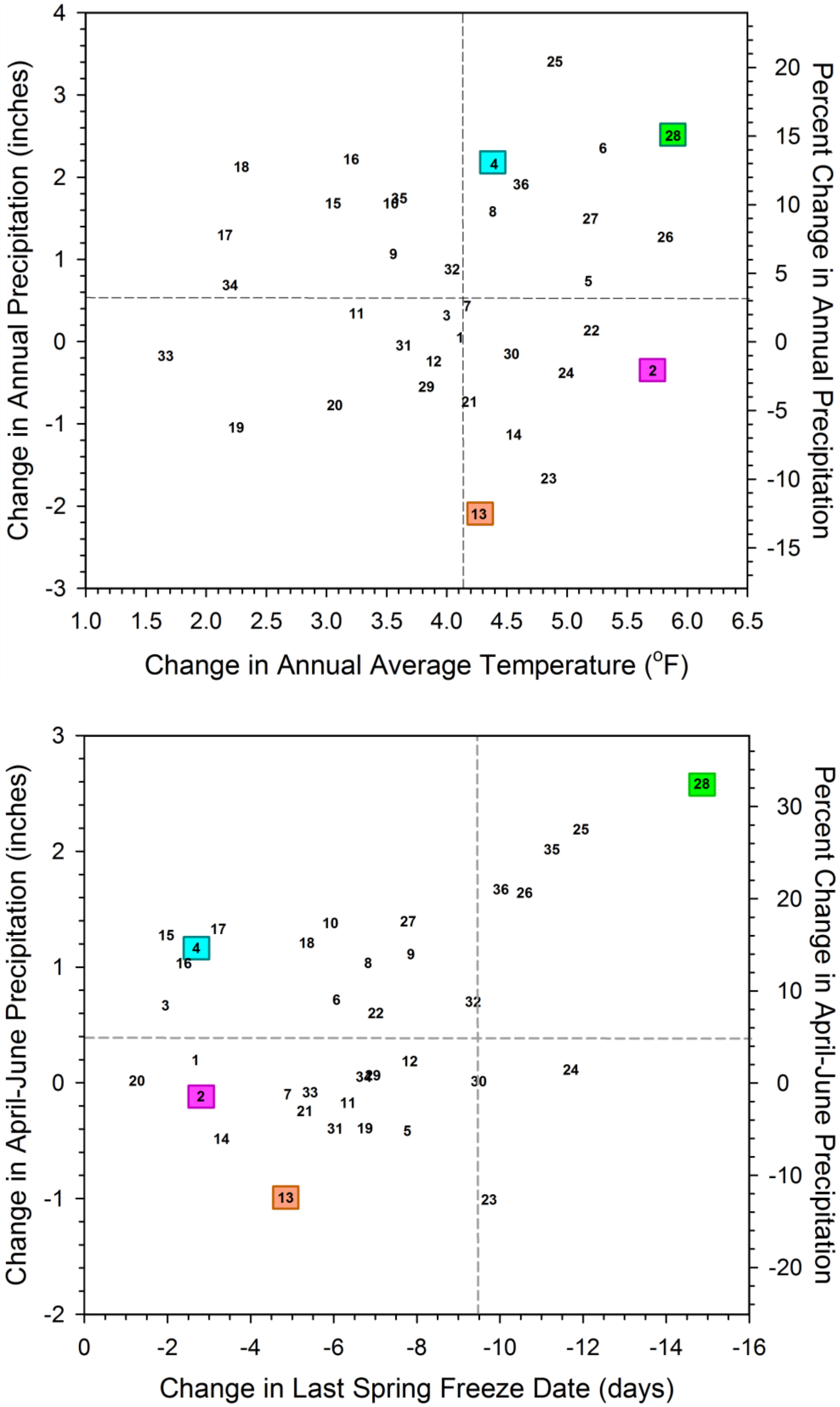


Figure 11. continued next page

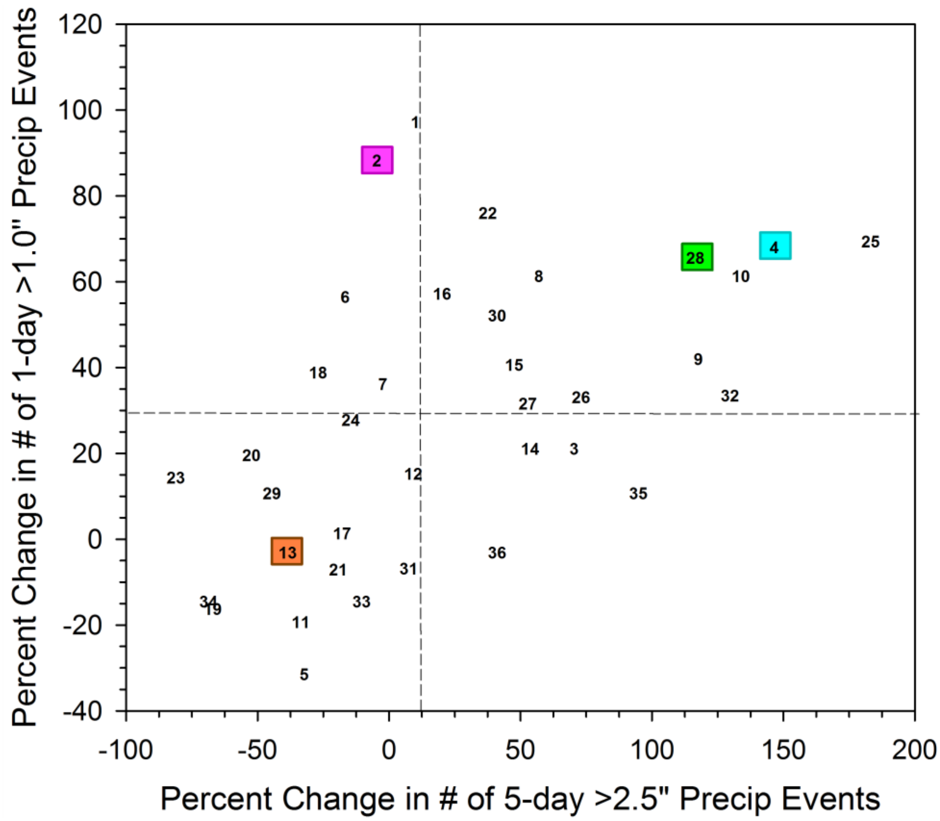


Figure 11. Annual temperature and precipitation changes (upper panel), spring (April-June) precipitation and last spring freeze date changes (middle panel), and changes in 1-day and 5-day heavy precipitation events (lower panel) for individual climate projections. Data are downscaled from 18 CMIP5 Global Climate Models (GCMs). Each GCM was run with a moderate (Representative Concentration Pathway [RCP] 4.5) and business as usual high greenhouse gas emissions (RCP 8.5), and values shown in this figure are for a grid cell centered in the bison range of Badlands National Park (climate data from Reclamation 2013). Values are changes from 1950-99 to 2020-2050. Numbers in colored boxes are projections selected for scenarios. The specific GCM projections chosen for scenarios are #2, access1-0.1.rcp85; #13, csiro-mk3-6-0.1-rcp45; #4, bcc-csm1-1.1.rcp85; and #28, miroc_esm-chem.1.rcp85 (see Appendix 1 for full GCM names and methodological details). Box fill color corresponds with the color of the climate scenario used throughout this document. Dashed lines indicate the median value for each axis.

Southwest South Dakota Climate Scenarios

We developed four climate scenarios for southwest South Dakota to explicitly consider important uncertainties in near-term changes to heavy precipitation events, for their effects on erosion (Stetler 2013), and factors of growing season climate shown to be important to ecosystem productivity (Rogler and Haas 1947, Smart et al. 2007). These climate scenarios are alternative climatic conditions that could play out in the coming decades (2020-2050) and are characterized by four basic qualities: plausible, challenging, relevant, and divergent (NPS 2013). The climate scenarios are intended to specifically challenge managers' thinking on implications for archeological and paleontological sites, upland grasslands, wildlife, and park operations. These climate projections were chosen because they are particularly challenging (i.e., at the hotter end of projections, Figure 11 upper panel) and to capture divergence (or spread) in management-relevant climate variables such as annual precipitation, spring precipitation, the onset and length of growing season, and heavy rain events (Figure 11 middle and lower panels). Climate projection data are from Reclamation (2013) and are compared to a 1950-1999 historical baseline (Maurer et al. 2002); see Appendix 1 for methods. Scenario descriptions, including text, figures (12-20), and a table (1) provided to workshop participants are reproduced below.

Climate Scenario Descriptions (2020-2050)

"Rather Hot" (#2, access1-0.1.rcp85). The warming trend of the past two decades continues, and the magnitude of change for this scenario is at the high end of projections for mid-century. The annual average temperature increases by more than 5.5 °F, with more warming occurring in winter and summer (+6 to 7 °F) than spring and fall (+4 to 5 °F). Growing season length increases by about 30 days, but the average last spring freeze date stays about the same. Spring and annual precipitation are essentially unchanged (-1 to -2%), though the spring precipitation peak is spread more evenly over the April-June period than historically. This combination leads to the least change in soil moisture of any of the scenarios. This scenario has the greatest percentage increase in the frequency of 1-day extreme precipitation events (+90%), but the frequency of 5-day extreme precipitation events is unchanged.

"Awfully Dry" (#13, csiro-mk3-6-0.1-rcp45). The increase in annual average temperature in this scenario (+4.3 °F) is near the middle of model projections, and the greatest part of that warming occurs during the growing season (June-September, +6 °F). Growing season length, however, increases only by 15 days, the least of all the scenarios, because of relatively small increases in minimum temperatures in early spring. Similarly, the average last spring freeze date is only about 5 days earlier. This scenario is the driest of all (more than 2 inch decrease in annual precipitation), with 90% of that drop occurring in June-August. Not surprisingly, this scenario has the lowest soil moisture, falling by 8-12% through most of the year and by more than 15% in June. As would be expected in a dry scenario, the frequency of longer (5-day) extreme precipitation events decreases (~40%); however, 1-day extreme events occur about as often as historically.

"Wet in Bursts" (#4, bcc-csm1-1.1.rcp85). This scenario is characterized by some of the highest precipitation (+2") and frequency of extreme precipitation events (~70% increase in 1-day events and

~150% increase in 5-day events). Much of the increase in precipitation occurs during the early growing season (April-June +1”). “Wet in Bursts” also refers to the increased interannual variability of precipitation in the projected vs. historical period in this scenario. Warming is close to the middle for model projections (+4 °F), with most of that warming occurring in early winter, especially in minimum temperatures (+6 to 7 °F). Late winter-early spring minimum temperatures increase only moderately, though (+2 to 2.5 °F), so late spring freezes remain common and the growing season increases only by about 17 days. A bump in September-October precipitation is not enough to offset warmer fall temperatures when it comes to soil moisture, but the big increase in spring precipitation yields 5-10% higher soil moisture during much of the growing season.

"The Jungle" (#28, miroc_esm-chem.1.rcp85). As its name implies, this is the hottest and wettest scenario of all, with annual average temperature increasing by almost 6 °F by mid-century, and annual precipitation increasing by 2.5” (13%). As in many of the scenarios, much of the warming occurs in the winter, but in contrast to the previous scenarios, The Jungle’s cool-season warming extends into spring as well. Consequently, growing season lengthens by almost 35 days, and in this scenario, that is accompanied by the last spring freeze occurring 15 days earlier on average than historically. The big increase in precipitation comes from a 3” boost over April- May, but June-July precipitation drops by an inch. Extreme precipitation events increase by about the same amount as in the “Wet in Bursts” scenario, and there are some big swings in annual precipitation from year to year. Because of the concentrated early spring precipitation and the high temperatures, soil moisture drops precipitously between May and June (Jun 1-Jul 1 in the soil moisture graphs), falling from almost 20% higher than historical levels in May (Jun 1 on soil moisture figure) to essentially the same as historical levels by August 1.

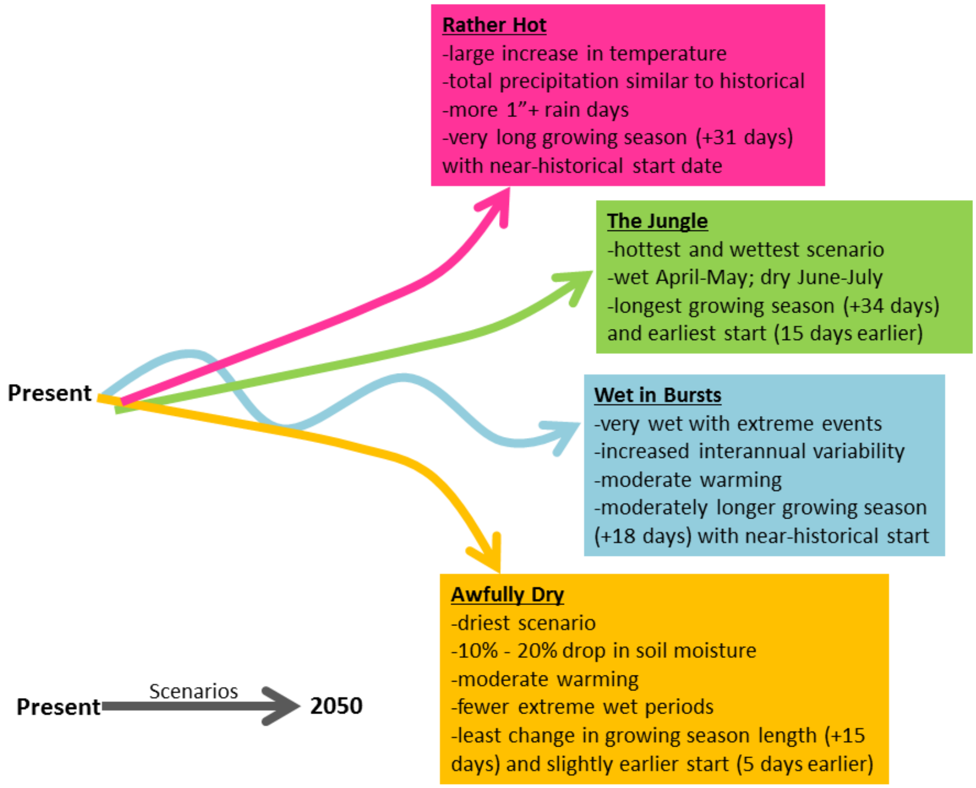


Figure 12. Conceptual diagram of key characteristics for each southwest SD climate scenario.

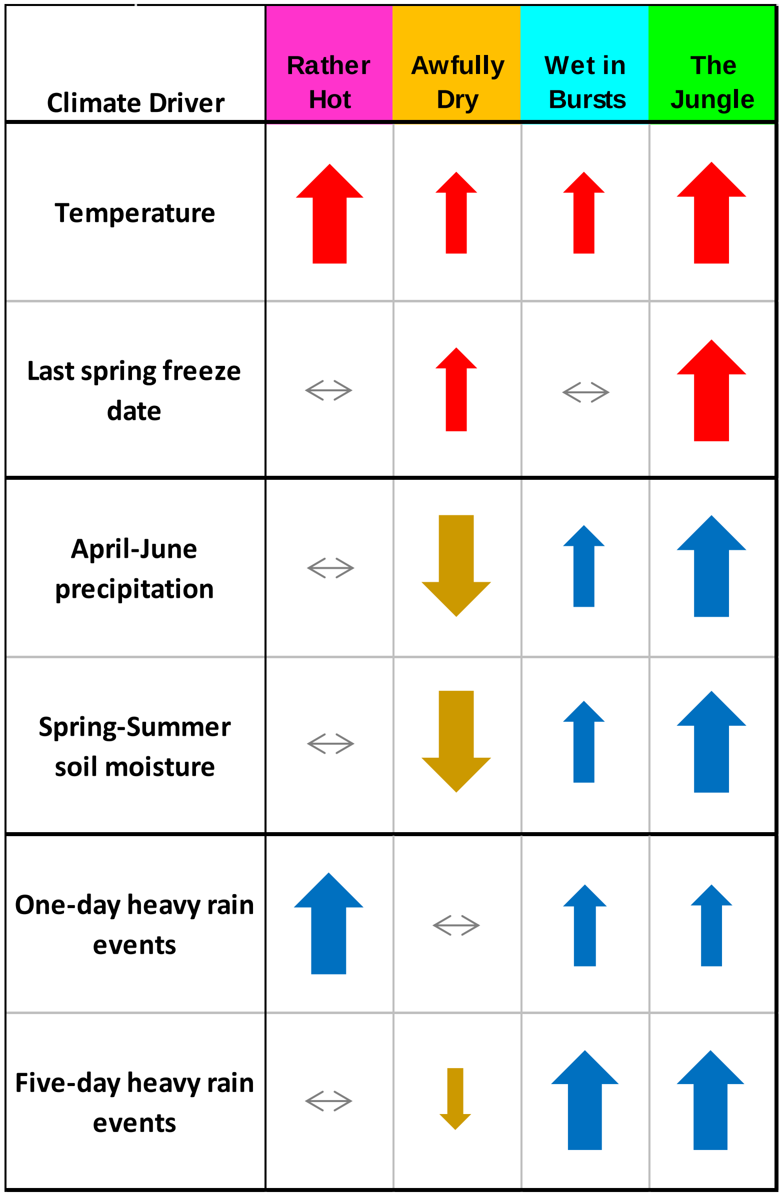


Figure 13. Climate drivers for the next 35 years (through 2050) for the southwest South Dakota climate scenarios. Arrow size and direction denote trends compared with the past (1950-1999). Down arrows denote decreasing trends, up arrows increasing trends and earlier dates, and sideways arrows indicate no change from historical conditions. Arrow size denotes the magnitude of change. Arrow color denotes warming (red), wetting (blue), drying (tan), and no change from the past (gray).

Table 1. Climate drivers for the next 35 years (through 2050) for the southwest South Dakota scenarios. Values are averages for the target future period (2020-2050) compared with the 1950-1999 historical period.

Driver	**Rather Hot***	**Awfully Dry***	**Wet in Bursts***	**The Jungle***
Annual temperature	+5.7 °F	+4.8 °F	+4.4 °F	+5.9 °F
Seasonal temperature	W: +7.2 °F Sp :+4.0 °F Su: +6.4 °F Fa: +5.2 °F	W: +3.9 °F Sp: +6.2 °F Su: +5.0 °F Fa: +4.2 °F	W: +5.3 °F Sp: +2.4 °F Su: +5.0 °F Fa: +4.8 °F	W: +6.7 °F Sp: +6.5 °F Su: +5.6 °F Fa: +4.7 °F
Growing season length	+31 days/yr	+15 days/yr	+18 days/yr	+34 days/year
Last freeze date	3 days earlier	5 days earlier	3 days earlier	15 days earlier
Annual precipitation	-0.4" (-2%)	-2.1" (-13%)	+2.2" (+13%)	+2.5" (+15%)
Seasonal precipitation	W: +0.5" (+41%) Sp: +0.7" (+13%) Su: -1.3" (-20%) Fa: -0.3" (-8%)	W: +0.2" (+21%) Sp: +0.1" (+1%) Su: -2.1" (-32%) Fa: -0.3" (-10%)	W: +0.1" (+10%) Sp: +1.2" (+21%) Su: +0.1" (+2%) Fa: +0.7" (+25%)	W: +0.3" (+31%) Sp: +2.9" (+51%) Su: -0.8" (-12%) Fa: +0.03" (+1%)
April-June precipitation	-0.1" (-2%)	-1.0" (-13%)	+1.2" (+15%)	+2.6" (+33%)
Frequency of days with >1" precipitation	+88%	-3%	+68%	+65%
Freq. of 5-day periods with >2.5" precipitation	-5%	-39%	+146%	+116%
Spring (Mar, Apr, May) soil moisture	+3%	-7%	+8%	+11%
Spring soil moisture (% of years > historical mean)	45%	19%	52%	71%
Summer soil moisture (Jun, Jul, Aug)	-7%	-13%	+6%	+4%
Summer soil moisture (% of years > historical mean)	23%	10%	45%	45%

* W = winter (December, January, February); Sp = spring (March-May); Su = summer (June-August); Fa = fall (September-November)

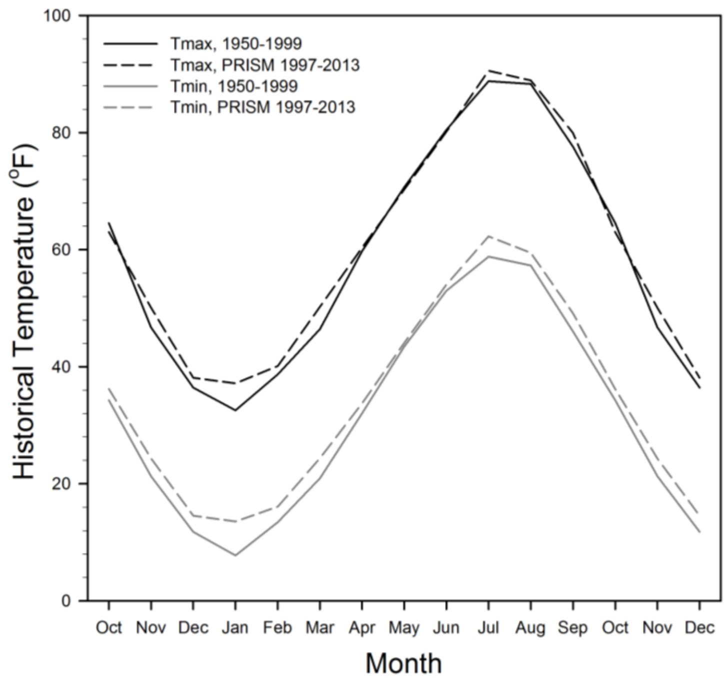


Figure 14. Historical and recent monthly temperature profile. Tmax: average maximum temperature; Tmin: average minimum temperature (daily values averaged across each month); solid lines: 1950-1999 (from Maurer et al. 2002); dashed lines: 1997-2013 (from PRISM Climate Group, prism.oregonstate.edu). Although the two datasets of historical temperatures (i.e., for the same dates) are quite similar, the more recent data from the PRISM dataset indicate seasonal patterns in recent warming trends. The horizontal axis in this and following graphics shows 15 months (October to December) to represent both the water year and calendar year, and to better visualize the full cold-season.

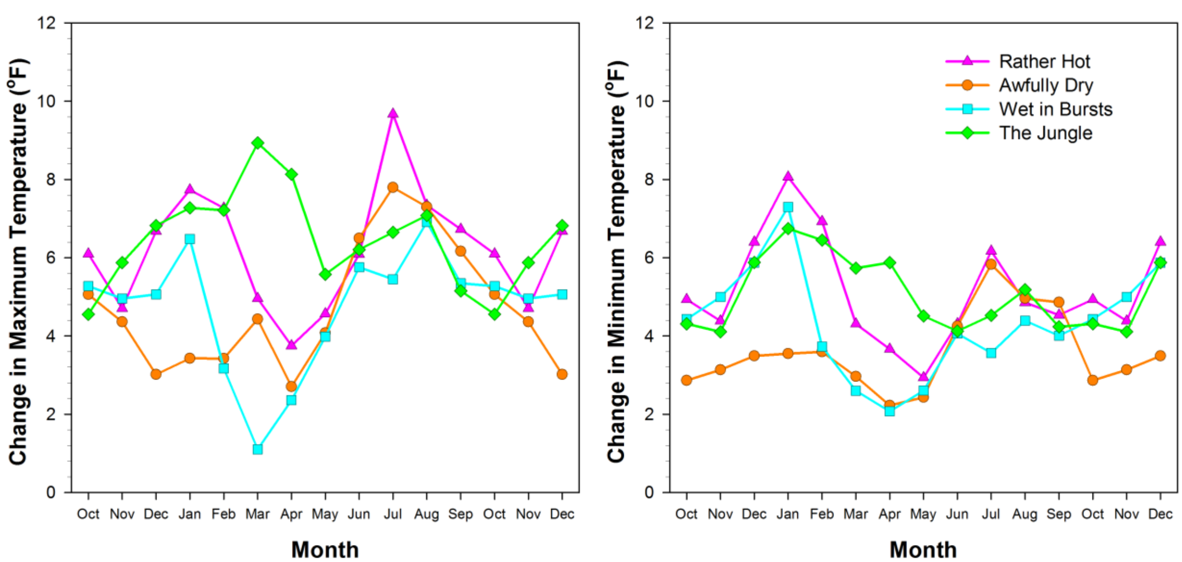


Figure 15. Scenario (2020-2050) monthly maximum (left) and minimum (right) temperatures (2020-2050) as departures from 1950-1999 average.

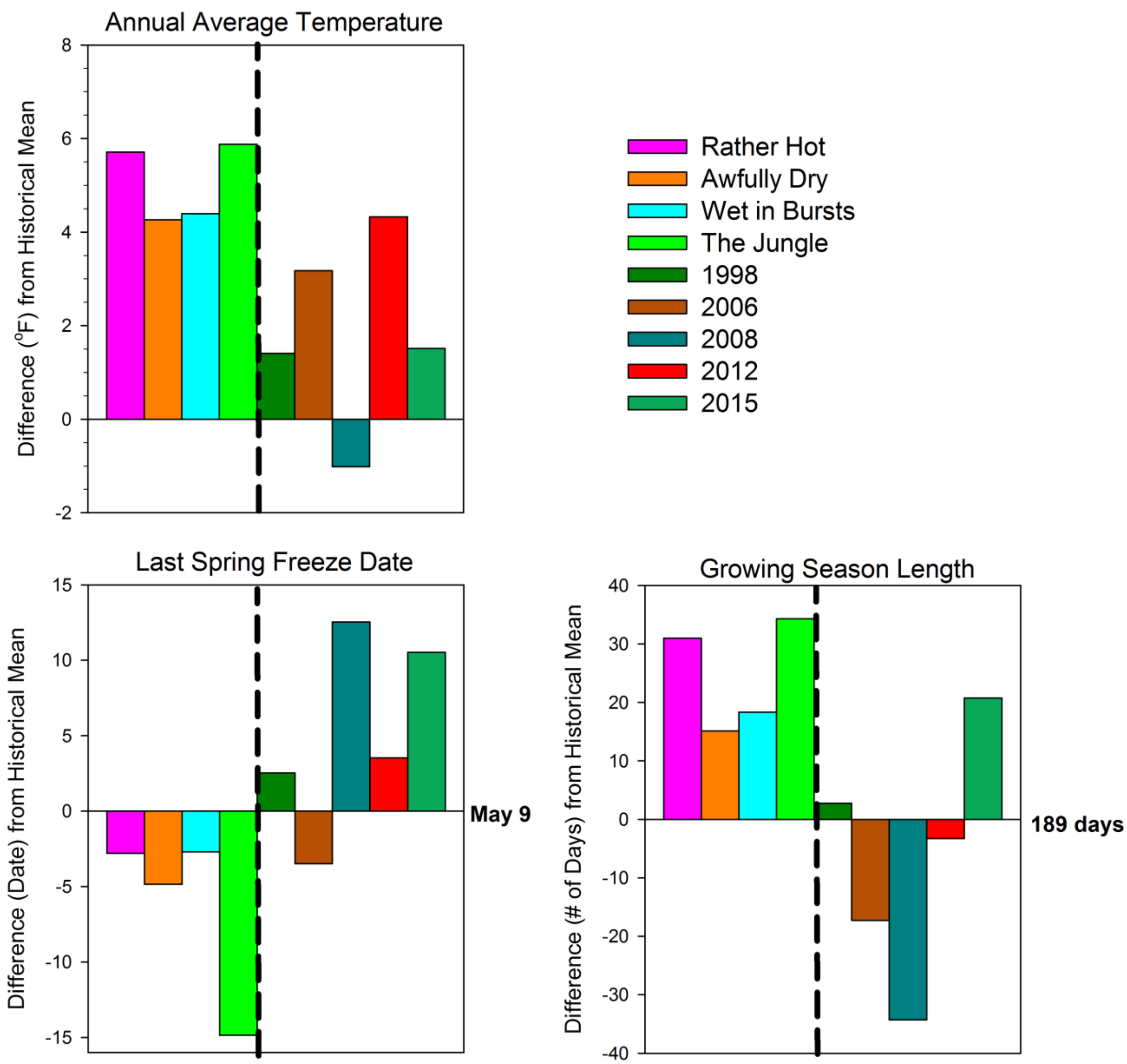


Figure 16. Differences in annual average temperature (top), last spring freeze date (bottom left), and growing season length (bottom right) between scenarios (2020-2050 average) and their historical (1950-99) average (bars left of dashed line in each graph). Bars right of the dashed line in each graph show differences between 5 single years and the historical (1956-99) average for the Interior, SD, weather station (GHCND: USC00394184). These years were chosen for their recency and strong departures from historical average annual (1998, 2006, 2012) or spring (2015) precipitation and frequency of extreme precipitation events (2008). Last spring freeze date is the last day in a calendar year before July 1 that the minimum temperature is < 32 °F (0 °C). Growing season length is defined as the number of days between the first (spring) instance of 6 consecutive days where each has an average temperature > 41 °F (5 °C) and the first (fall) instance of not having 6 consecutive days of average temperature > 41 °F (5 °C). Historical mean values for last spring freeze date and growing season length are given to the right of each 0-difference line.

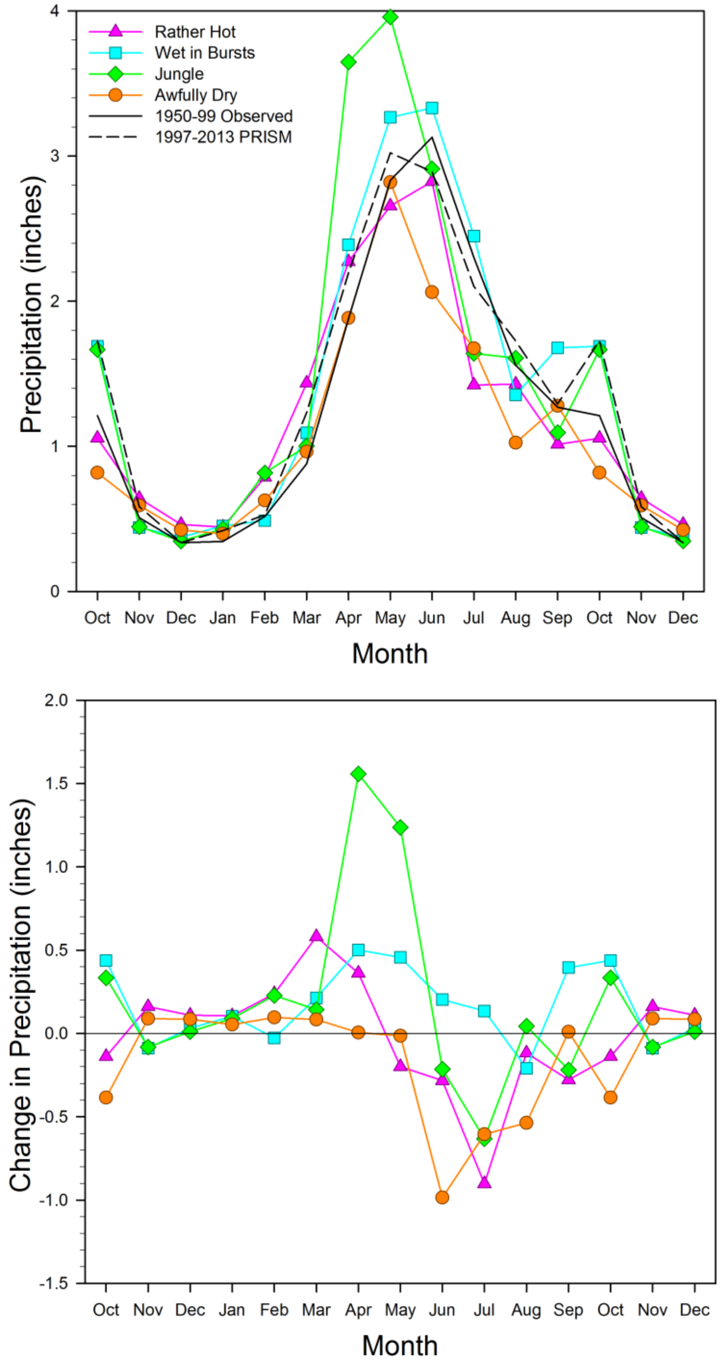


Figure 17. Monthly precipitation profiles for scenarios. Top: Long-term average monthly precipitation in scenarios (2020-2050) and two historical periods (1950-1999, 1997-2013). Bottom: Difference in long-term average monthly precipitation between scenarios and 1950-1999 historical period.

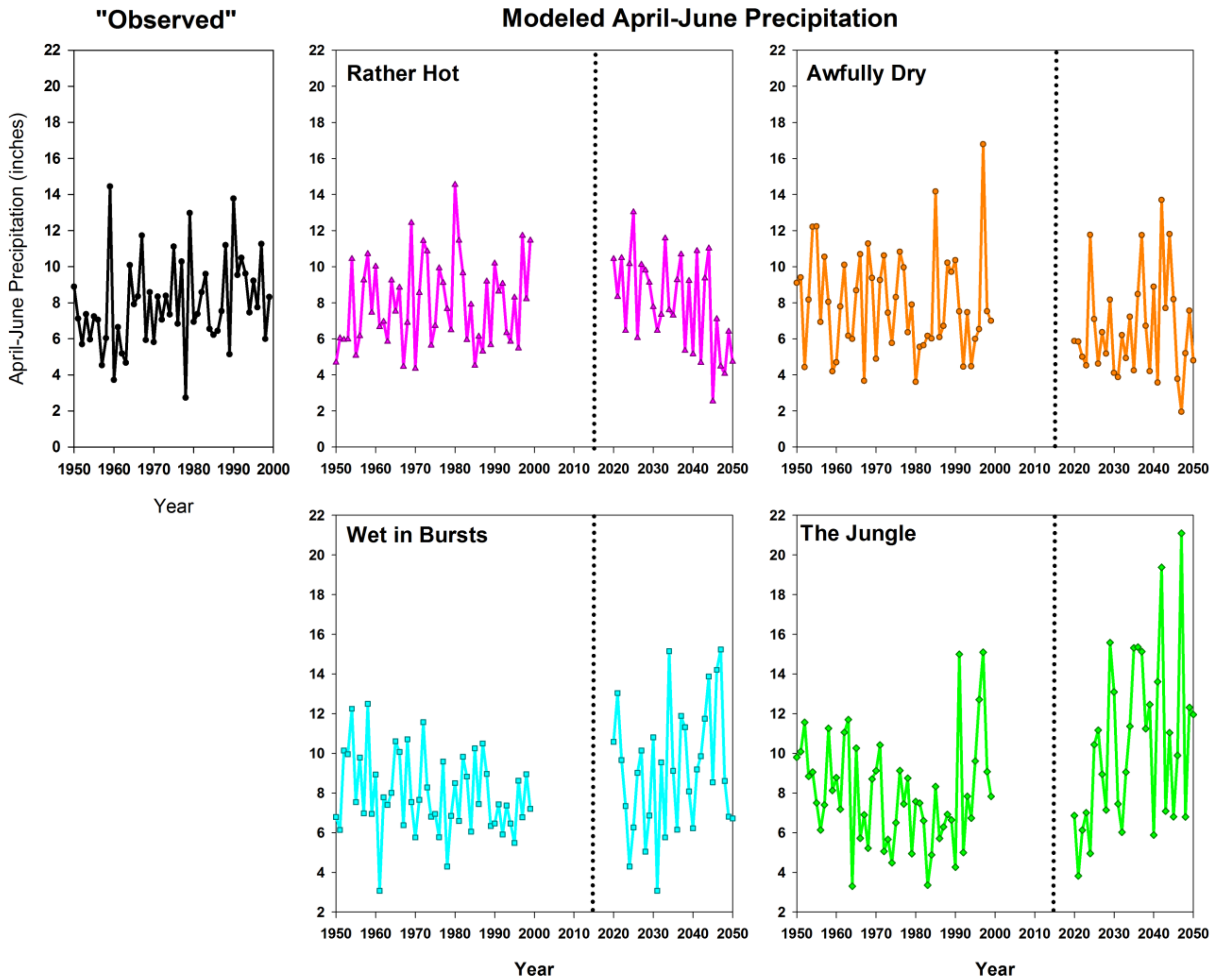


Figure 18. Time series of April-June precipitation of the simulated historical and projected periods, illustrating interannual variability in models (colored graphs). The “Observed” graph (black line, upper left) provides reference of observed variability during the historical period (1950-1999).

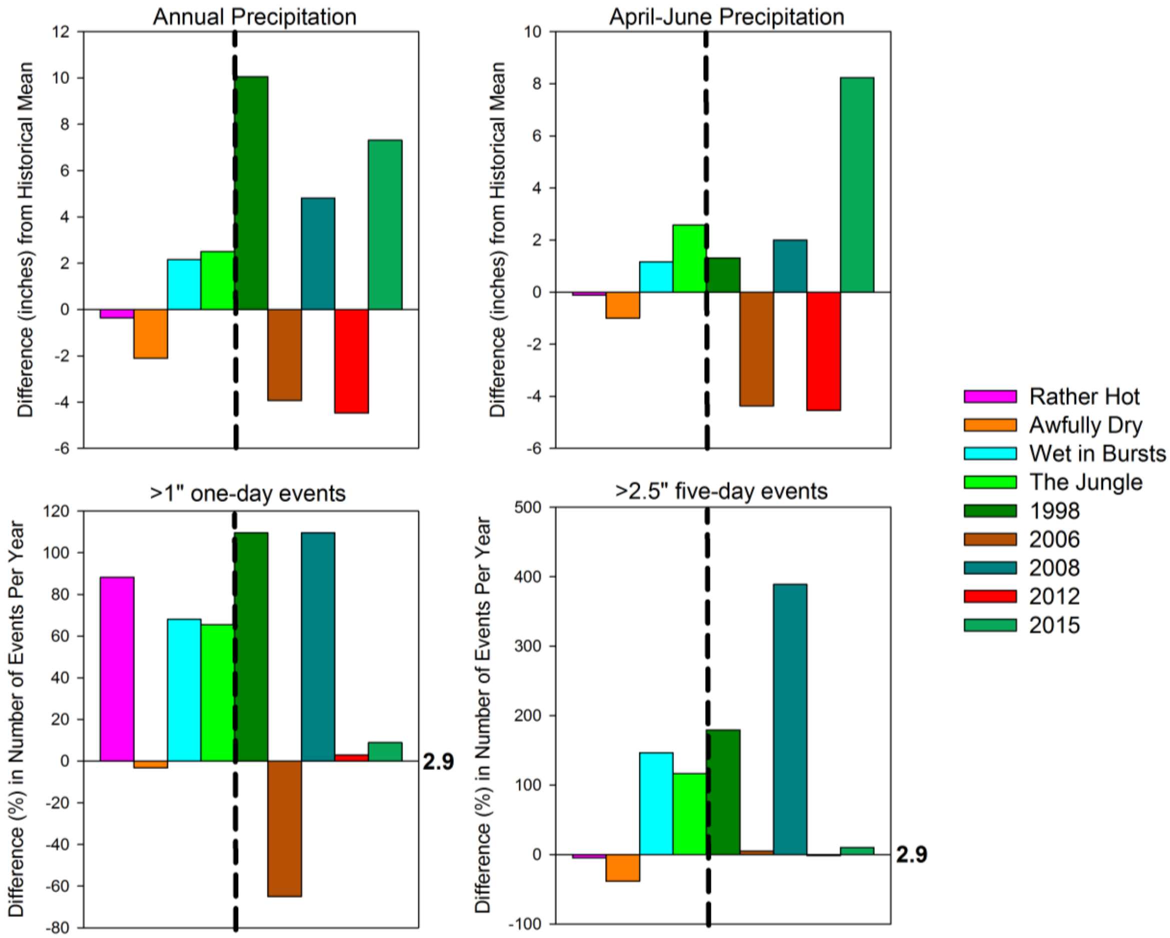


Figure 19. Differences in precipitation metrics between scenarios (2020-2050 average) and their historical (1950-99) average: annual precipitation (top left), April-June precipitation (top right), number of events per year in which >1" of precipitation falls in a single day (bottom left), and number of events per year in which >2.5" of precipitation falls in a five-day period (bottom right) (bars left of dashed line in each graph). Bars to the right of the dashed line show differences between 5 single years that are memorable in the recent record and the historical (1956-99) average for the Interior, SD, weather station (GHCND: USC00394184). Numbers next to 0-difference line for precipitation events are the historical averages from weather station data.

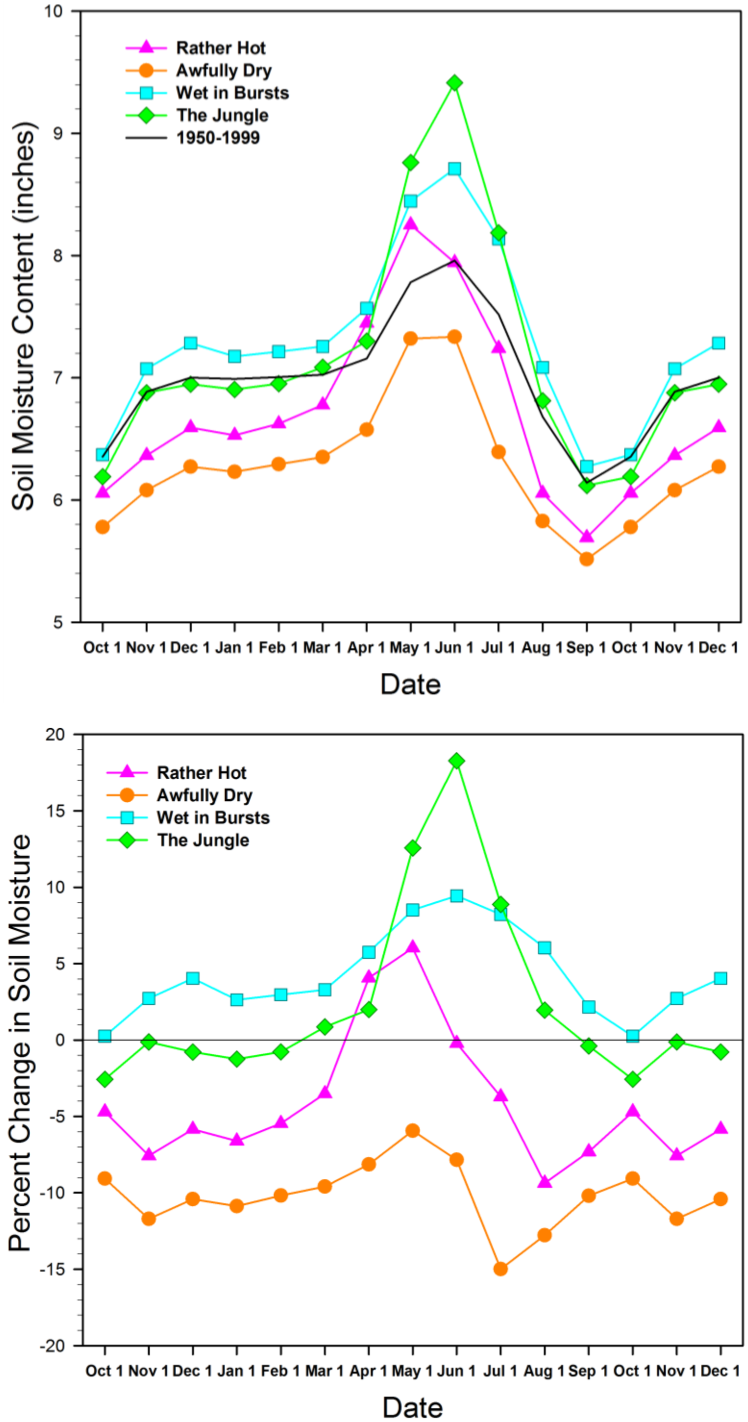


Figure 20. Monthly soil moisture profiles for scenarios. Top: Historical (1950-1990, black line, from Maurer et al. 2002) and scenario (2020-2050) long-term average monthly soil moisture. Bottom: Scenario monthly soil moisture (2020-2050) as departures (% change) from the 1950-1999 average.

Scenario Implications

Workshop participants separated into groups and each group examined the implications of a single climate scenario on focal resources and potential socio-political developments (Table 2; see Appendix 2 for more details). Examining potential socio-political developments fosters a broad exploration of potential future conditions beyond the simple resource response to climate. The descriptions below are from these small-group discussions in a workshop setting and should not be taken as vetted research statements of responses to the climate scenarios, but rather as insights and examinations of possible futures based on local expert science and management knowledge. Common topics included changes in agricultural practices, flooding impacts, vegetation productivity, invasive species, and maintenance needs. More intense storms, especially under Rather Hot, Wet in Bursts, and The Jungle, were envisioned to lead to greater erosion and impacts to archeological resources, paleontological resources, and infrastructure. Increased poaching and vandalism of archeological and paleontological resources was highlighted in Wet in Bursts. Changes in vegetation occurred in all scenarios and ranged from strong decreases in productivity and a shift towards shortgrass prairie (in Awfully Dry) to increased productivity, tallgrass prairie expansion, exotic plant invasion, and woody encroachment (in The Jungle). These changes in vegetation would affect grazers, including bison and prairie dogs, and the species dependent on them, such as black-footed ferrets. Warmer and wetter conditions were thought likely more conducive to plant, animal, and human diseases.

Table 2. Workgroup-envisioned developments and resource implications for climate scenarios.

Developments and Resources	**Rather Hot**	**Awfully Dry**	**Wet in Bursts**	**The Jungle**
Socio-political	• More social pressure on publicly managed lands	• Increased conflicts among landowners due to expansion of prairie dog towns and escaping bison	• Decreased recreation • Increased agriculture, decreased ranching • Budgets strained due to high maintenance costs	• Agriculture (including corn) increases, grassland decreases • Land prices increase • Shift in fire season and lack of crews in fall • More plant, animal, and human diseases
Cultural Resources (including archeological sites)	• More archeological sites exposed	• Less erosion from water, more from loss of vegetation (bare ground) and wind • Increased fire danger to archeological sites	• Major erosion exposes many sites • Increased poaching and vandalism • Water damage to historical structures • More educational opportunities, enhances individual responsibility	• Lose archeological sites to erosion and vegetation growth • Culturally significant trees persist
Geological Resources (including paleontological sites)	• More fossils exposed due to erosion and mass wasting	• Less erosion from water, more from loss of vegetation (bare ground) and wind	• Major erosion exposes many sites • Increased poaching and vandalism • Geohazards exposed • More educational opportunities, enhances individual responsibility	• Vegetation destroys fossils • Heavy rain events wash away fossil sites • Wet soils cause disintegration (crumbling) of fossils at/near ground surface • More ungulates leads to fossil trampling & site degradation

Table 2 (continued). Workgroup-envisioned developments and resource implications for climate scenarios.

Developments and Resources	Rather Hot	Awfully Dry	Wet in Bursts	The Jungle
Natural Resources (including grasslands and grazing)	• Less forage, less water, fewer bison • More prairie dog acreage and associated species	• Drought-adapted species persist • Less forage, less water, fewer bison • Shortgrass species expand • Increase in wildlife disease with concentration around water sources	• More water for wildlife (but inconsistent) • Increased ticks, mosquitoes, and pathogens they carry • Increased challenge to match stocking rates to annual productivity	• Higher vegetation productivity therefore increased cattle, bison • Shift to tallgrass prairie leads to the disappearance of swift fox • Greater woody encroachment • Less prairie dog acreage • Weeds increase (cheatgrass, sweetclover, Canada thistle) • Later/longer fall fire season
Facilities / Infrastructure / Other	• More road damage from flooding • Less backcountry / more frontcountry use	• Increased need for bison roundup facilities • New erosion issues due to wind and more bare ground rather than water	• Degradation of roadway infrastructure • Lack of museum facility space for salvage collections	• Degradation of roadway • Challenge keeping up with slumps, floods, mowing • More visitors, especially in shoulder seasons

Testing Goals and Actions

Climate change and other global change stressors not only challenge land managers' abilities to protect natural areas but also demand that we re-think conservation concepts, goals, and actions in a continuously changing world (Hobbs et al. 2010, NPS AB 2012, Fisichelli et al. 2015). Climate change adaptation is, in simple terms, adjustment to changing conditions. It is, more formally, "adjustment in natural or human systems in anticipation of or response to a changing environment in a way that effectively uses beneficial opportunities or reduces negative effects" (*Executive Order No. 13653*, 2013).

Adaptation frameworks can be useful to structure thinking, incorporate climate change into decisions, and ensure that the full spectrum of adaptation options is considered. Adaptation strategies can be described as a spectrum from resisting change, through accommodating change, to directing change (Figure 21, Fisichelli et al. 2016; see also Millar et al. 2007, Stein et al. 2014). "Resist change" strategies aim towards persistence by maintaining current or past conditions. A "direct change" strategy actively manages a resource towards new, specific desired conditions. In an "accommodate change" strategy, the target responds to climate change, and management intervention supports its capacity to do so without seeking to drive the system towards a specific state. There is no single adaptation option that is appropriate in all situations; rather, the appropriate strategy will vary across resources, space, and time. For example, many persistence strategies are suitable in the near term but are likely to become increasingly risky and costly as time goes on (Millar et al. 2007). Management response to climate change therefore needs to be continuous and continually reassessed.

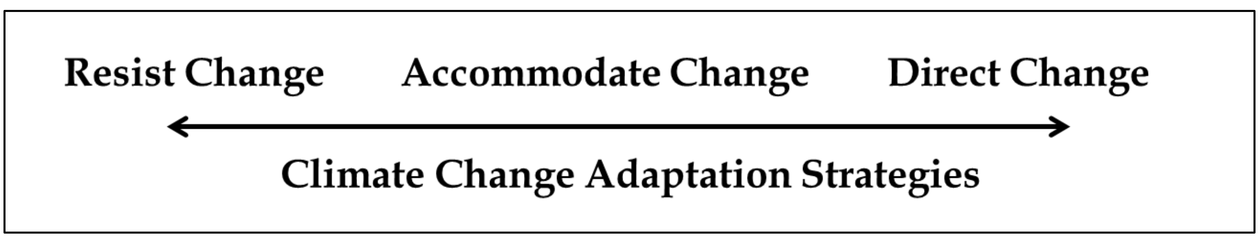


Figure 21. Climate change adaptation is about managing change and includes a spectrum of strategies from resisting to directing change. Appropriate strategies will vary across resources, space, and time. Figure adapted from Fisichelli et al. (2016).

Another adaptation framework is aligning goals and actions with climate change (Figure 22; adapted from Stein et al. 2014). This framework includes three categories: business as usual, climate retrofit, and climate rebuild. In "business as usual", current goals and actions are deemed appropriate and effective based on climate change vulnerability assessments including the climate conditions and timeframe of the project. With "climate retrofit", current goals are retained, but achieving them under changing conditions will require revised actions. Finally, under "climate rebuild", neither current goals nor actions are tenable, and thus revisions to both are necessary for success. Inland fisheries management provides a useful example. If maintaining a cold-water fishery (goal) through annual stocking (action) is feasible given the range of projected changes in conditions, then this would be considered "business as usual". Under warming conditions, this goal may still be achievable (climate retrofit) but require revised actions of more frequent (biannual) stocking and stream shading. Assuming an extremely climate-vulnerable fishery, the existing goal of a cold-water fishery may not be achievable using any available adaptation actions. Under a “climate rebuild”, a revised goal may be to establish a warm-water fishery with the action of managed relocation.

Figure 22. Aligning goals and actions in climate change adaptation. Depending on impacts and vulnerability to climate change, adaptation will vary from keeping current goals and actions to revising both goals and actions. *Review and revise as needed. Figure adapted from Stein et al. (2014).

Scenarios provide a platform for strategic conversations. Most commonly, scenarios help teams generate ideas about what they might do or change under a new set of conditions, as well as identify indicators to monitor to detect changing conditions and adjust actions. In the context of climate change adaptation, scenarios provide the setting for examining the efficacy of a range of plausible management responses.

Thus, in the next phase of the workshop, teams examined five management topics – archeological and paleontological resources, vegetation, bison, black-footed ferret, and infrastructure – and aligned goals and actions (as in Figure 22) with the conditions of each scenario. The descriptions below summarize the outcomes of these discussions (detailed notes are in Appendix 3), and Table 3 highlights which approach was deemed most appropriate in each scenario. The descriptions are from these small-group discussions in a workshop setting and thus should not be taken as vetted research statements of responses to the climate scenarios.

Table 3. Workgroup assessment of the achievability of current goals versus needed revisions by 2050 for five resources. The likely achievable adaptation responses shown in the table below include ‘Business as Usual’ (current goals and actions), ‘Climate Retrofit’ (current goals and revised actions), and ‘Climate Rebuild’ (revised goals and actions) (Figure 22). See text for details of each resource’s current and revised goals and actions.

Resource	Rather Hot	Awfully Dry	Wet in Bursts	The Jungle
Archeological and Paleontological	Retrofit/Rebuild	Business as Usual	Retrofit/Rebuild	Retrofit/Rebuild
Native Vegetation	Business as Usual/Retrofit	Business as Usual/Retrofit	Retrofit/Rebuild	Retrofit/Rebuild
Bison	Retrofit	Retrofit	Retrofit	Retrofit
Black-footed Ferret	Business as Usual	Business as Usual	Retrofit	Retrofit
Infrastructure, Roads, and Geohazards	Retrofit/Rebuild	Business as Usual	Retrofit/Rebuild	Retrofit/Rebuild

Archeological and Paleontological Resources

Current goals for archeological and paleontological resources are preservation and protection. For this exercise, the workgroup focused on a specific location within Badlands National Park – Big Buffalo Basin. There are multiple concurrent actions under this goal, including surveying, site stabilization, salvage/data recovery, and law enforcement to mitigate theft and looting. This broad goal was seen as achievable in the near-term and long-term under all scenarios; however, major additional actions may be needed. Greater erosion due to heavier rain events in Rather Hot, Wet in Bursts, and The Jungle make it very difficult to keep up with erosion rates and preserve and protect newly exposed artifacts and sites. Additional needs include increased salvage collection, cooperative agreements, and in-house staffing for additional field surveys, citizen science, and fund raising. Visitor education and outreach will need to be increased to build awareness of fossil poaching. Wet conditions would hamper field work. The timing of other park operations and the influence of the academic calendar on seasonal employee availability may also constrain when and how much field work gets done. Also, enhanced GIS modeling to identify potential sites would aid management. Prioritizing archeological sites for stabilization and data recovery may be needed. Under these challenging scenarios, however, it is not clear how best to prioritize due to uncertainties in the quality and quantity of resources at unexcavated sites. Past experience has shown that it is easy to overlook sites that may in the future produce significant finds. The increased exposure of sites may provide some opportunity for greater education and interpretation. The workgroup deemed current actions sufficient under the Awfully Dry scenario, but noted that these low-erosion conditions would present fewer opportunities for fossil and archeological site discovery.

Native Vegetation

The native vegetation workgroup used an approximation of the existing Forest Service goal: 30-60% of vegetation in the “historical climax plant community”, 10-20% in each of late-intermediate and early-intermediate stages of succession, and 10% of vegetation in an early successional stage, as often occurs on prairie dog towns. Current actions on Forest Service and Park Service lands include prescribed fire, invasive plant management (biological and chemical control), and grazing. Forest Service uses cattle and has more flexibility in changing the grazing regime (stocking rate and timing of grazing) on its lands. The current goal is achievable in the short-term (2030) under the drier scenarios (Rather Hot and Awfully Dry). Looking out to 2050, the goal is still achievable on Forest Service lands in these scenarios, assuming management can be flexible and responsive. This flexibility includes the ability to adjust grazing leases (including the grazing species), to provide drinking water for grazers when and where needed, and to use prescribed fire more frequently as a management tool. The goal is more difficult to achieve in the long term on Park Service lands if current constraints on grazing and fire management remain and because the park has not assessed or mapped the existing successional vegetation types and approximate cover. On Park Service lands, more fire, greater control of grazing via fencing, flexible water sources, mineral lures, targeted prescribed fire, and potentially even domestic grazers may be needed to achieve the current goal. In Awfully Dry, both Services' goals may need to focus more on protecting and restoring riparian and wet areas.

Meeting the stated goal was even more challenging in the wetter scenarios (Wet in Bursts and The Jungle) because of expected increases in vegetation productivity, woody encroachment, and invasive plant abundance and diversity. Increasing the number of grazers to achieve the current grazing intensity would be required on all lands; on National Forest System lands, this would require revising current policy. Additionally, much greater invasive plant control will be needed.

Across all scenarios, historical conditions become much more challenging to achieve in the long term. Changes to the definition of the historical climax plant community (and even the term used for this late-successional community) may be necessary and would influence both the achievability of the goal and the necessary tools. Targeted monitoring is necessary to understand the rate of community changes. Wilderness designation on some Park Service lands is a further filter through which goals and actions must be assessed. Goals requiring intensive management intervention may not be achievable or suitable in these wilderness areas.

Bison

Bison are a major resource management emphasis in the region. For this exercise, current bison goals include maintaining optimal herd health, promoting genetic diversity, protecting range through stocking rates, and establishing herds on tribal lands for production and cultural use. Bison are able to survive in and adapt to a broad range of conditions. Thus, the workgroup saw bison as likely to persist across all scenarios and time periods. The limiting factor here is management and the ability to have proactive and reactive management responses that match the dynamism of the system and adaptability of bison.

In the reduced grassland productivity futures, especially Awfully Dry, bison herd size would need to be reduced and more round ups, potentially using a mobile corral system, may be needed. Because of decreased forage quality and availability, it may become more difficult to keep bison within desired areas, and additional fencing (double fencing or electric fencing) will be required. Supplemental feed and water sources, including tanks and storage ponds, may be needed to both meet bison needs and reduce pressure on existing natural water sources. However, supplemental feeding within Badlands National Park would require policy change. Due to increased drought occurrence, greater education about and livestock producer enrollment in USDA drought insurance programs may be needed.

Different management challenges and solutions exist in the wetter scenarios (Wet in Bursts and The Jungle). Bison carrying capacity and calving rates will increase with increased vegetation productivity; however, round ups in the park would become more challenging because of the ample supply of natural water sources in wet years and difficulty of attracting bison to the existing corral area with water (a current strategy). Wet, muddy terrain could also make it difficult to conduct roundups. Warmer and wetter conditions increase health and disease concerns, and will require enhanced monitoring and potentially development of new vaccines for emerging diseases. Across scenarios, the workgroup thought that a participatory and inclusive regional bison plan is warranted, and possible new actions include the development of best-practices or guidelines for bison genetics and breeding, a bull exchange program, and revised culling strategies based on the most modern genetic tools and scientific techniques, along with input from those who will receive bison.

Black-footed Ferret

Goals and actions for the black-footed ferret focus on prairie dogs, its primary prey. The current goal identified for the workshop exercise is to expand present prairie dog colonies (acreage), and associated actions are managing plague by dusting prairie dog holes with a flea-control insecticide, and continued monitoring. The current goal is likely achievable in the short and long term in the Rather Hot and Awfully Dry scenarios. Dry conditions favor expansion of prairie dog towns because shorter vegetation reduces perceived predation risk. Reduced forage for cattle may increase pressure from permittees to manage and reduce the extent of prairie dog towns, and expanded partnerships and strengthened relationships among stakeholders are needed. A healthy black-footed ferret population in the region could bolster ecotourism.

The workgroup found the current goal to be unachievable across all time periods in the wetter scenarios (Wet in Bursts and The Jungle) due to changes in vegetation (taller vegetation and woody encroachment). Revised actions in these scenarios include more intensive grazing and an expanded management area for black-footed ferrets. In the long term of The Jungle, a revised goal may be prairie dog acreage maintenance rather than expansion. Permittees are likely to support increased grazing in these scenarios, but will be challenged by the annual fluctuations in stocking rates. Across all scenarios, plague and future disease dynamics are major concerns. Black-footed ferrets can disperse and travel to separate, isolated prairie dog populations during plague outbreaks, assuming sufficient habitat connectivity and prairie dog town proximity.

Infrastructure, Roads, and Geohazards

For the infrastructure and roads workgroup, the current goal is to maintain safety and usability with the current actions of routine maintenance and emergency response after major disturbance events. With greater extreme precipitation events in three of the futures (Rather Hot, Wet in Bursts, and The Jungle), the status quo will likely be challenged. Greater erosion would cause more frequent maintenance requirements. This increasing need, along with budget pressure and inadequate staffing levels, may lead to unachievable workloads. In the short term, additional culverts and greater investment in equipment may achieve the current goal, though there are likely to be increased inconveniences, due to road closures, for residents and visitors alike. In the long term, difficult tradeoffs and revised goals are likely required in these futures. Conversations about road access, fees, weight limits, and controlled seasonal access will be needed.

Operationalizing Scenario Planning Outcomes

Scenario planning offers multiple benefits, including revealing assumptions and providing insights about a system. The scenarios also provide accessible storylines that lend themselves to outreach and communication about the risks and challenges linked with management decisions in the face of very different potential future climate and socio-economic conditions. Sharing such descriptions with expanded stakeholder groups can be an important precursor, particularly for public agencies, to implementing the changes some future trajectories might require. More intensive application can test whether existing plans and ideas about adaptation options remain effective across a wide range of plausible, potential futures. The final phase of the workshop focused on this more intensive application by describing approaches and tools for participants to build the uncertainty represented by the more fully developed scenarios into their management planning and implementation.

In conditions under which existing plans and options fall short, scenarios can be used to help revise current options and develop new ones. The result is sets of options for each scenario, some of which will be common to all futures while others will be unique to the particular conditions of a given scenario or subset. This type of exercise can generate a portfolio of options, where the investment in specific options is anticipated to shift over time as the future plays out. Creating a portfolio of management options is likely the most useful way to work with the scenarios, because it matches options with corresponding potential futures and establishes a framework for their application.

Figure 23 shows three stages in working with climate change adaptation options generated through scenario planning exercises (H. Hartmann, personal communication). The stages may be used individually or in sequence, based on planning needs. In the first stage, options are organized using simple time-based decision trees that distinguish which options to pursue in the near-term from those to implement later as conditions change. Decision points for shifting options and associated indicators of significant changes in climate or other conditions are identified up front and included in the decision tree.

A portfolio of management options based on divergent scenarios typically includes both familiar management actions and new or challenging ideas. Thus, in the second stage, options are evaluated and categorized as ‘no regrets’ or ‘hard’ choices; this can help prompt adaptation. ‘No regrets’ options (e.g., control invasive species) confer numerous benefits and implementation may be widely supported. ‘Hard choice’ options may be more controversial and difficult to implement, and they should be considered carefully. ‘Hard choices’ may also be complicated and take time to execute. Breaking down ‘hard choice’ options may reveal some activities that need to be completed in advance (e.g., permitting), as well as ‘no regrets’ components that can be more easily carried out (H. Hartmann, personal communication). Thus, in the third stage, ‘hard choices’ are disaggregated into steps; these are incorporated into the decision tree, thereby setting up a strong framework to operationalize management options in response to the most challenging and uncertain futures. Managing for changing conditions requires forward-looking goals and preparatory steps well in advance of actions.

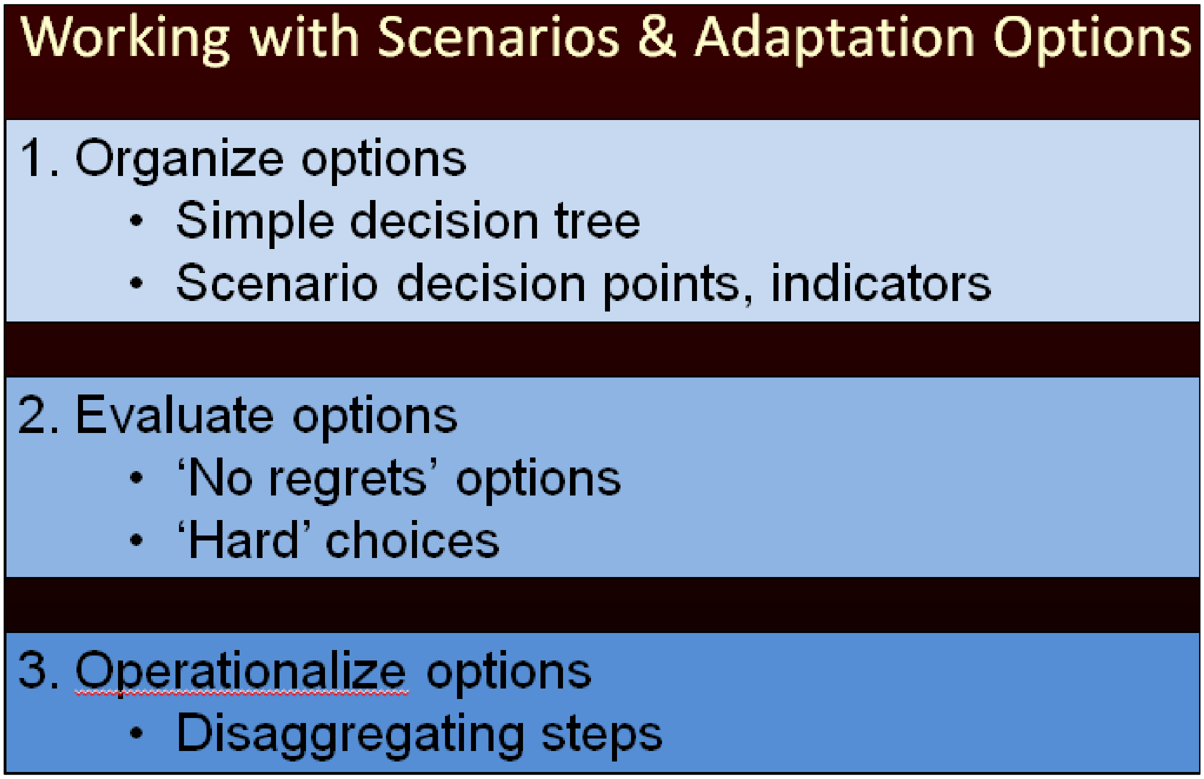


Figure 23. Disaggregating a portfolio of options into a temporal decision tree with key decision points and indicators helps operationalize adaptation. Figure from H. Hartmann and USFWS National Conservation Training Center.

At the end of the workshop, workgroups explored operationalizing potential options through disaggregating steps and identifying triggers (Appendix 4). Each resource group chose a potential action (one that is different from current practice), identified triggers for monitoring that would indicate when the action is applicable, and created a timeline of steps needed to implement the action. For example, the potentially controversial action of restricting sensitive paleontological resource site access to only land management staff and permitted individuals might begin with setting the stage in broad strategic planning documents and then developing potential actions through the NEPA process. Outreach to the public and consultation with tribal partners would be needed to build support for restrictive management actions. The resource group identified triggers linked to the decision point that included significant rain events and erosion, budget cuts, staff attrition, and inability of fossil documentation work to keep pace with accelerated erosion. Fund raising for increased surveys and salvage collection would also need to be completed.

Additional work is needed to embed the scenario planning outcomes into planning and decisions about the on-the-ground implementation of the climate change adaptation options. This is the role of the participants after the workshop described in this report. This project's science team will further support this work with a quantitative simulation model of vegetation dynamics (including the influence of fire, grazing, invasive species, climate, and management actions on grassland composition and production) in the study area. This model will be used to explore system responses to the climate scenarios and management alternatives identified during and after the scenario planning workshop. The science team will share the findings from this modeling exercise (e.g., revelations about data gaps, surprising system dynamics, and/or comparisons of management outcomes) during a second workshop. Materials from the scenario planning workshop, including this report, as well as materials from the second workshop, provide support for participants to incorporate the insights from this project into adaptation planning. However, adaptation is an iterative process (Stein et al. 2014), and the scenario planning process described here is just one contribution. Project team members will assess the utility of the scenario planning process for resource management decisions to improve outcomes in future iterations with collaborative teams of managers, planners, scientists, and adaptation specialists.

Literature Cited

Amberg, S., K. Kilkus, S. Gardner, J. E. Gross, M. Wood, and B. Drazkowski. 2012. Badlands National Park: Climate change vulnerability assessment. Natural Resource Report NPS/BADL/NRR—2012/505. National Park Service, Fort Collins, Colorado.

[Executive Office of the President. 2013.] Executive Order 13653: Preparing the United States for the impacts of climate change, November 1, 2013, 78 Federal Register 66817.

Fisichelli, N., G. Schuurman, and E. Sharron. 2015. Climate change: responding to the crisis portended by George Perkins Marsh. *George Wright Forum* 32:276-289.

Fisichelli, N. A., G. W. Schuurman, and C. Hawkins Hoffman. 2016. Is 'resilience' maladaptive? Towards an accurate lexicon for climate change adaptation. *Environmental Management* 57:753-758.

Gregory, R., L. Failing, M. Harstone, G. Long, T. McDaniels, and D. Ohlson. 2012. Structured decision making: a practical guide to environmental management choices. John Wiley & Sons, Oxford, UK.

Hobbs R. J., D. N. Cole, L. Yung, E. S. Zavaleta, G. H. Aplet, F. S. Chapin III, P. B. Landres, D. J. Parsons, N. L. Stephenson, and P. S. White. 2010. Guiding concepts for park and wilderness stewardship in an era of global environmental change. *Frontiers in Ecology and the Environment* 8:483–490.

Kunkel, K. E., L. E. Stevens, S. E. Stevens, L. Sun, E. Janssen, D. Wuebbles, M. C. Kruk, D. P. Thomas, M. D. Shulski, N. A. Umphlett, K. G. Hubbard, K. Robbins, L. Romolo, A. Akyuz, T. B. Pathak, T. R. Bergantino, and J. G. Dobson. 2013. Regional climate trends and scenarios for the U.S. National Climate Assessment – Part 4. Climate of the U.S. Great Plains. NOAA Technical Report NESDIS 142-4, National Oceanic and Atmospheric Administration, Washington, D.C.

Lauenroth, W. K., I. C. Burke, and M. P. Gutmann. 1999. The structure and function of ecosystems in the central North American grassland region. *Great Plains Research* 9:223-259.

Martin, T. G., M. A. Burgman, F. Fidler, P. M. Kuhnert, S. Low-Choy, M. McBride, and K. Mengersen. 2012. Eliciting expert knowledge in conservation science. *Conservation Biology* 26:29-38.

Maurer, E. P., A. W. Wood, J.C. Adam, D. P. Lettenmaier, and B. Nijssen. 2002. A long-term hydrologically based dataset of land surface fluxes and states for the conterminous United States. *Journal of Climate* 15:3237-3251.

McBride, M. F., F. Fidler, and M. A. Burgman. 2012. Evaluating the accuracy and calibration of expert predictions under uncertainty: predicting the outcomes of ecological research. *Diversity and Distributions* 18:782-794.

Millar C. I., N. L. Stephenson, S. L. Stephens. 2007. Climate change and forests of the future: managing in the face of uncertainty. *Ecological Applications* 17:2145–2151.

National Park Service (NPS). 2013. Using scenarios to explore climate change: a handbook for practitioners. National Park Service Climate Change Response Program. Fort Collins, Colorado.

National Park System Advisory Board (NPS AB). 2012. Revisiting Leopold: resource stewardship in the national parks. Washington, DC. Available: http://www.nps.gov/calltoaction/PDF/LeopoldReport_2012.pdf. Accessed 2014 May.

Peterson, G. D., G. S. Cumming, and S. R. Carpenter. 2003. Scenario planning: a tool for conservation in an uncertain world. *Conservation Biology* 17:358-366.

PRISM Climate Group, Oregon State University, http://prism.oregonstate.edu.

Reclamation. 2013. 'Downscaled CMIP3 and CMIP5 Climate and Hydrology Projections: Release of Downscaled CMIP5 Climate Projections, Comparison with preceding Information, and Summary of User Needs', prepared by the U.S. Department of the Interior, Bureau of Reclamation, Technical Services Center, Denver, Colorado. 47pp. Data downloaded from http://gdo-dcp.ucllnl.org/downscaled_cmip_projections/dcpInterface.html#Welcome 22 October 2015.

Rogler, G. A. and H. Haas. 1947. Range production as related to soil moisture and precipitation on the Northern Great Plains. *Journal of the American Society of Agronomy* 39:378-389.

Rowland, E., M. Cross, and H. Hartmann. 2014. Considering multiple futures: scenario planning to address uncertainty in natural resource conservation. U.S. Fish & Wildlife Service. Available at: http://www.fws.gov/home/climatechange/pdf/Scenario-Planning-Report.pdf

Smart, A. J., B. H. Dunn, P. S. Johnson, L. Xu, and R. N. Gates. 2007. Using weather data to explain herbage yield on three Great Plains plant communities. *Rangeland Ecology & Management* 60:146-153.

Stein, B. A., P. Glick, N. A. Edelson, and A. Staudt. 2014. Climate-smart conservation: putting adaptation principles into practice. National Wildlife Federation, Washington, DC. Available at: http://www.nwf.org/pdf/Climate-Smart-Conservation/NWF-Climate-Smart-Conservation_5-08-14.pdf

Stetler, L. 2013. Determining erosion rates at select fossil sites to develop a paleontological monitoring program. Final Report to the NPS, housed at the BADL Resource Management Office. 222 pp.

Appendix 1. Climate scenario creation methods.

The scenario creation process used climate output from the World Climate Research Programme's (WCRP's) Coupled Model Intercomparison Project phase 5 (CMIP5) multi-model dataset, which was used for the IPCC Fifth Assessment (IPCC 2013). That climate output is the basis for two statistically downscaled products that we used, originally developed for the U.S. Bureau of Reclamation. The Bias-Correction Constructed Analogue (BCCA) statistically downscaled product for CMIP5 projections was done at a daily time step, whereas the bias-corrected and spatially disaggregated (BCSD) dataset was done in monthly time steps; both were spatially downscaled to a ⅛ degree (~12km or 7.5 miles) grid. We downloaded both products using the "Projections: Subset Request" tool at http://gdo-dcp.ucllnl.org/downscaled_cmip_projections/dcpInterface.html#Projections:%20Subset%20Request. For BCCA we downloaded precipitation and maximum and minimum temperature data for a grid cell centered at 43.8125° latitude and -102.3125° longitude (in the bison range of Badlands National Park), for two greenhouse gas emissions pathways (the moderate Representative Concentration Pathway [RCP] 4.5 and the high RCP 8.5).

Hydrological variables at a monthly time step are available as the product of running BCSD climate through the Variable Infiltration Capacity (VIC) hydrology model (Reclamation 2013; http://gdo-dcp.ucllnl.org/downscaled_cmip_projections/). We downloaded soil moisture data from this hydrology dataset for the same grid cell, with the understanding that BCCA and BCSD are very slightly different; however, the hydrology data are only available for the BCSD product. The two products (BCCA climate and BCSD hydrology) both downscaled the same run for each of 18 climate models and two emissions pathways, for a total of 36 projections.

For each of these projections, we calculated a variety of climate and soil moisture metrics dictated by the scenario planning workshop's focal resource issues, then used these to select climate scenarios. These metrics included spring (April-June) precipitation, onset and length of growing season, and frequency of heavy rain events. We then calculated the difference in these metrics between the 1950-1999 historical period (Maurer et al. 2002) and a 2020-2050 planning period. We considered absolute changes and percent change compared to the historical period for annual and monthly maximum and minimum temperature, precipitation, and soil moisture; annual number of events per year in which >1" of precipitation falls in a single day; annual number of events per year in which >2.5" of precipitation falls in a five-day period; and annual last spring freeze (minimum temperature < 32 ºF) date. We also considered time series of annual spring precipitation.

We visually inspected graphics of the metrics (some of which are presented in the main text), chose four projections that "push the envelope" by posing relevant challenges for management, and gave them descriptive, memorable names for ease of use during the workshop. The names and projections were "Rather Hot" [#2, access1-0.1.rcp85 (Australian Community Climate and Earth System Simulator)]; "Awfully Dry" [#13, csiro-mk3-6-0.1-rcp45 (Commonwealth Scientific and Industrial Research Organisation Mark 3.0)], "Wet in Bursts" [#4, bcc-csm1-1.1.rcp85 (Beijing Climate Center)], and "The Jungle" [#28, miroc_esm-chem.1.rcp85 (Model for Interdisciplinary Research

On Climate)]. Using a specific projection for a climate scenario ensures that climate scenarios are internally consistent (physically coherent) and provides specific climate input for the quantitative modeling component of this project. However, choosing a small number of scenarios requires balancing a set of tradeoffs. We could have selected scenarios with a greater divergence in the range of annual precipitation vs. temperature (Figure 11 upper panel), but previous experience in scenario workshops has shown that "moderate" scenarios (i.e., relatively little change in mean annual temperature and total precipitation) do not stimulate workshop participants' discussion and are often side-lined. In addition, changes in mean annual temperature and total precipitation often do not represent changes in variables (e.g., soil moisture) that are most relevant to the local resource concerns. Therefore, climate scenarios were chosen to capture divergence in the management-relevant climate variables determined during the orientation phase of the project and informed by scientific literature on the focal resources (Figure 11 middle and lower panels). For this reason, these scenarios do not represent the full range of projected changes in mean annual temperature – they exclude the lower range of temperature changes, although they do capture much of the range in annual precipitation.

Pierce et al. (2009) discussed the number of global climate model (GCM) projections required to derive estimates of regional climate change, and found that 14 projections from five GCMs were sufficient to represent a full set of the 21 CMIP3 model results. So, in this project, the 18 GCMS are more than enough to represent the full spread of the models. The four GCMs we selected are a subset intentionally chosen to represent the spread, or divergence, of management-relevant variables within this larger spread.

Literature Cited in Appendix 1

Intergovernmental Panel on Climate Change (IPCC). 2013. Climate change 2013—The physical science basis, *in* Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S. K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex, and P. M. Midgley, eds. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change: Cambridge, United Kingdom, Cambridge University Press, 1535 p.

Maurer, E. P., A. W. Wood, J.C. Adam, D. P. Lettenmaier, and B. Nijssen. 2002. A long-term hydrologically based dataset of land surface fluxes and states for the conterminous United States. *Journal of Climate* 15:3237-3251.

Pierce, D. W., T. P. Barnett, B. D. Santer, and P. J. Gleckler. 2009. Selecting global climate models for regional climate change studies. Proceedings of the National Academy of Sciences (USA) 106:8441-8446.

Reclamation. 2013. 'Downscaled CMIP3 and CMIP5 Climate and Hydrology Projections: Release of Downscaled CMIP5 Climate Projections, Comparison with preceding Information, and Summary of User Needs', prepared by the U.S. Department of the Interior, Bureau of Reclamation, Technical Services Center, Denver, Colorado. 47pp. Data downloaded from http://gdo-dcp.ucllnl.org/downscaled_cmip_projections/dcpInterface.html#Welcome 22 October 2015.

Appendix 2. Workgroup Scenario Storyline and Impacts Worksheets

Scenario workgroups assessed conditions within each scenario, additional features, and implications for resources. This appendix is provided so that participants of the workshop can review their workgroup exercises and to provide ideas for others wishing to use scenario planning.

SD Scenario: 2016-2050 Rather Hot

In your scenario: Increased growing season

Climate Features:
• Increased temperature (winter, July max) • More rain instead of snow in winter • Increased 1" rain events • Spring / early summer soil moisture near historical levels • Longer growing season • Dry lightning
What other developments might occur? (e.g., sociopolitical, economic)
• More social pressure on publicly managed lands

What happens to:

Cultural Resources (including archeological sites)	**Geological Resources (including paleontological)**
• More flooding • More archeological sites exposed	• More erosion • More fossils exposed • More mass wasting
Natural Resources (including grassland & grazing)	**Facilities / Infrastructure / Other**
• Lower forage / less bison • Less water availability • Increase in prairie dog acreage (if plague mitigated) • Increase in black-footed ferrets, foxes, burrowing owls • Increase/ decrease in reptiles/amphibians • Change in species, migration patterns • *plague might benefit from changes in climate?	• Higher energy costs • More flooding impacts • Road failure • Visitation changes • Less backcountry/ more front country • Pressure on facilities • More vehicles • More interpretation needs

SD Scenario: 2016-2050 Awfully Dry

Alternative name suggested during workshop: "Normal is just a setting on the dryer"

In your scenario:

Climate Features:
• Increased summer temperatures (+6 degrees Fahrenheit) • Decreased precipitation and soil moisture • Increased growing season (2 weeks) • Earlier last spring freeze • Decreased intense rain events • Cyclical drought and severity
What other developments might occur? (e.g., sociopolitical, economic)
• Expansion of prairie dogs therefore increased tension / conflict • Bison escapes? / trespassing • Decreased staff available due to increased wildfire across west

What happens to:

Cultural Resources (including archeological sites)	Geological Resources (including paleontological)
• Increased need to identify and protect newly discovered resources • Increased looting due to exposure • Increased fire would be a danger to ethno. resources (e.g. burial scaffolds, railroad pieces, homesteads) • Exposure of archeological sites (due to more bare ground and wind erosion)	• Increased soil instability due to decreased vegetation • Exposure of new sites (due to more bare ground and wind erosion) • Desiccation makes soil more prone to washing away
Natural Resources (including grassland & grazing)	**Facilities / Infrastructure / Other**
• Drought adapted species able to persist • Decreased grass and water, grazing capacity • Increased exotics & forbs & woody sp. (e.g. Russian thistle) • Change in plant community, short grass replaces mid grass, increase in rhizomatous grasses? • Increase in prairie dog population • Change in bison movement patterns • Increased wildfire (good & bad?) – late season rain could lead to 2nd green up • Decreased efficiency of Canada thistle • Biocontrol agents • Increase in wildlife disease with concentration around water sources	• Increased soil instability due to decreased vegetation • Increased need for roundups + facilities, but easier to round them up (just add water) • Roundup overlap w/ rut? • Increased need for fire and noxious weed management • Increased need for pest management (pine beetle) • Increased wildlife disease with concentration around water sources

SD Scenario: 2016-2050 Wet in Bursts (First of two workgroups)

In your scenario:

Climate Features:
• Very wet, wet extremes • "Swings" in rainfall, heavy rain events, moderately longer growing season. • Moderate increase in temperature, yet this is still much warmer than historical period
What other developments might occur? (e.g., sociopolitical, economic)
• No change in research funding (arch., paleo.), decreased visitation/camping • Budget issues (more spent per year on maintenance)

What happens to:

Cultural Resources (including archeological sites)	**Geological Resources (including paleontological)**
• Weathering / revealing more sites • Flooding of sites • Poaching / vandalism • Damage to historical structures (e.g. b/c of deferred maintenance) • Damage to historical juniper trees • More educational opportunities, enhances individual responsibility	• Weathering / revealing more sites • Flooding of sites • Poaching / vandalism • Geohazards exposed • Increased slope failure • Increase in exposure of fossil sites • More educational opportunities, enhances individual responsibility
Natural Resources (including grassland & grazing)	**Facilities / Infrastructure / Other**
• Green until mid-August • More water for wildlife (yet inconsistent) • Lower protein (veg. inconsistent) • Increased amphibians, reptiles, waterfowl habitat • Increased ticks, mosquitoes, and pathogens they carry • Increased exotic plant species, harder to manage • Decreased water quality "too thick to drink too thin to farm" • More difficult to do round ups (bison)	• Erosion of roads • Degradation of roadway infrastructure • Road closures • Increase in flood-related rescues • Increase in "piping" erosion • Maintenance budget, staff time (e.g. cleaning silt) • More educational / opportunities / interpretation

SD Scenario: 2016-2050 Wet In Bursts (Second of two work groups)

Alternative name suggested during workshop: "Bipolar Hydrology / Splash N' Burn"

In your scenario:

Climate Features:
• Increased extreme weather events • Increased flooding and drought • Increased temperature • Increased frost-free days • Increased annual precipitation • Increased soil moisture (especially May 1st through August 1st)
What other developments might occur? (e.g., sociopolitical, economic)
• Increased conversion – cropland (private) • Decreased ranching • Fire funding pressures • Increased pressure to privatize public lands

What happens to:

Cultural Resources (including archeological sites)	**Geological Resources (including paleontological)**
• Increased exposure and possible destruction of sites • Increased pressure on cultural resources (cultural landscapes)	• Increased pressure by collectors of agates due to increased exposure • Increased exposure and possible destruction of fossil sites • Increased poaching of fossils • Increased mass wasting of geological features
Natural Resources (including grassland & grazing)	**Facilities / Infrastructure / Other**
• Increased off road travel and impacts to resources • Increased risk / challenge stocking rates • Increased invasion of exotic noxious weeds • Decreased diversity of grassland ecosystems • Increased variability in mammal populations • Increased pathogens for plants and wildlife • Increased fire • Increased trees	• Increased pressure on recreational facilities (such as those in gate-rich areas) • Increased pressure on water infrastructure • Increased road failure • Lack museum storage for salvage collections

SD Scenario: 2016-2050 The Jungle: (First of two work groups)

In your scenario:

Climate Features:
• Temperature increase greatest in winter • Precipitation April – May increases while July – August decreases • 4 times increase in 5 day precipitation – increase in 1 day • Very dynamic soil moisture • Increased wet snow, blizzards • Windier • Fewer late spring freezes
What other developments might occur? (e.g., sociopolitical, economic)
• Fire crews not available in fall when fires are active due to seasonal nature of their employment

What happens to:

Cultural Resources (including archeological sites)	**Geological Resources (including paleontological)**
• Lose archeological sites to erosion and vegetation growth • Increased slope failure • Vegetation destroys fossils	• Increased slope failure • Vegetation destroys fossils
Natural Resources (including grassland & grazing)	**Facilities / Infrastructure / Other**
• Vegetation destroys fossils • Fruit production increases – if limbs do not break • Vegetation increases therefore increased cattle, bison? (☺ spring, ☹ summer) • Weeds increase • Disease and parasites increase • Later / longer fall fire season	• Increased slope failure • Vegetation destroys fossils • Challenge keeping up with slumps, floods, mowing • More visitors – but they are bug bitten

SD Scenario: 2016-2050 The Jungle: (Second of two work groups)

In your scenario:

Climate Features:
• Hottest and wettest scenario • Increase 6 degrees Fahrenheit • Longest growing season (35 days -15 days earlier start, 20 days later end) • Increase 2.5 inches of precipitation (April- May) • June – July precipitation drops • Increased extreme thunderstorms
What other developments might occur? (e.g., sociopolitical, economic)
• Corn increases • Grassland decreases • Land prices increase • Increased fee revenue • Increased expenses such as energy • Less conflict with neighbors – more well off

What happens to:

Cultural Resources (including archeological sites)	**Geological Resources (including paleontological)**
• More erosion of archeological and cultural sites • Visitor center and lodge trees improve • Increased flooding of buildings and campground • Increased fire damage –wildfire	• More erosion and exposure of paleontological resources • Geohazards increase – landslides • Increased poaching of fossils • New fossil discoveries • Greater stream flows
Natural Resources (including grasslands and grazing)	**Facilities / Infrastructure / Other**
• Cheatgrass nightmare weeds! • Yellow sweetclover and Canada Thistle • Shift to tallgrass prairie • Woody encroachment • Greater net productivity • Conditions favor grazers except prairie dogs • New bird species arrive • Less winter kill of wildlife • Increased wildfire fuel and intense fires in fall / late summer	• Greater / extensive road repair • Shoulder season – grater visitation • Some visitation increase in peak periods • Increased fence repair

Appendix 3. Testing Goals and Actions Worksheets

Workgroups examined current goals and actions for a variety of resources and then assessed whether possible goal and action revisions will be needed under the conditions of each scenario. This exercise does not mean the revisions or actions are actually being considered but rather the exercise was used to help managers think about the need for potential changes in goals and actions in the future.

Table A3-1. Issue/Resource: Paleontology/Archeology

Scenario	Current goals: Current actions	Achievable in short-term? Long-term?	Current goals: Revised actions	Revised goals: Revised actions	Insights, Tradeoffs?
Rather Hot	Goal: Preservation and protection of Big Buffalo Basin (for example purposes only) Actions: • Survey • Stabilization – paleo- small scale and short term • Salvage / data recovery • Law enforcement to mitigate theft / looting • Interpretation education	Short term – yes Long term – yes	Revised actions: • Increase salvage collection • Cooperative agreement for specimen storage • Cooperative agreement for field survey • Citizen science • GIS modeling • Increase surveys • Fund raising / crowd sourcing- particularly private sector match • Archeological site condition assessment	• Increased exposure (more rapidly) • May need more funding to mitigate	• Tribal consultation a necessity across all scenarios • Goals do not change but actions do
Awfully Dry	Same as above	Short term – yes Long term – yes	• Most stable: present actions will suffice	•	• Fewer opportunities for fossil / site discovery • Less opportunity for theft or looting • Goals do not change but actions do

Table A3-1 (continued). Issue/Resource: Paleontology/Archeology

Scenario	Current goals: Current actions	Achievable in short-term? Long-term?	Current goals: Revised actions	Revised goals: Revised actions	Insights, Tradeoffs?
Wet in Bursts	Same as above	Short term – yes Long term – yes	• Increased intensity of management response (most increase in intensity) • Work between rain periods	• Increased exposure leading to need for more emergency funding and crowd sourcing • Prioritize site stabilization and data recovery (archeological sites) • Target fossil-rich units • Restricted access	• Impact of academic year on staffing and constrained field season • Goals do not change but actions do
The Jungle	Same as above	Short term – yes Long term – yes	• Increased intensity of management response • Focus field work late summer when drier conditions persist	• Prioritize site stabilization and data recovery (arch) • Target fossil-rich • More rapid exposure increased emergency funding and crowd sourcing	• If seasonality impacts field work, must consider timing of other park operations • Impact of academic year on staffing and constrained field season • Goals do not change but actions do

Table A3-2. Issue/Resource: Native Vegetation

Scenario	Current goals: Current actions	Achievable in short-term? Long-term?	Current goals: Revised actions	Revised goals: Revised actions	Insights, Tradeoffs?
Rather Hot	Current Goals: • 30-60% HCPC (historic climax plant community), 10-20% Late Intermed, 10-20% Early Intermed, 10% Early dog town Current Actions: • FS: Rx grazing – timing, stocking rate intensity thru leases • NPS: fire, culling bison • Both: Biological & chemical control, roadside seeding	**FS:** 2030-yes 2050- yes if management flexible **NPS:** 2030 – yes 2050 – no (w/ current fire infrastructure)	**NPS** • More fire • More control of grazing • Fencing • Flexible water sources • Using Rx fire • Prairie dogs • Mineral lures • Cattle	• Forb –eating herbivores (sheep? Pronghorn?) • FS; more bison keep away from water • Plant approved native species • Targeted monitoring • Additional research	• Control vs. wilderness • Landscape/regional cooperation
Awfully Dry	Same as above	**FS:** 2030-yes 2050- yes if management flexible **NPS:** 2030 – yes 2050 – no (w/ current fire infrastructure)	• more fire • assume flexibility now being planned (Rx Grazing)	• revised goal: target riparian / wet areas for protection and restoration • NRCS changes HCPC • Plant approved native species • Targeted monitoring • Additional research	• Control vs. wilderness • Landscape/regional cooperation

Table A3-2 (continued). Issue/Resource: Native Vegetation

Scenario	Current goals: Current actions	Achievable in short-term? Long-term?	Current goals: Revised actions	Revised goals: Revised actions	Insights, Tradeoffs?
Wet in Bursts	Same as above	**FS:** 2030-no. Cap on herd size limits weed control with grazing; mud complicates operations 2050- no **NPS:** 2030 – no 2050 – no	**FS:** • increase grazing and cap • educate decision makers on importance of non-weeds (native species)	• Adopt new bio control tools for quick action • Plant approved native species • Targeted monitoring • Additional research	• Control vs. wilderness • Landscape/regional cooperation • Use forb-eating herbivores?
The Jungle	Same as above	**FS:** 2030-no. Cap on herd size limits weed control with grazing mud complicates operations 2050- no **NPS:** 2030 – no 2050 – no	**FS:** • increase grazing and cap • More helicopter spray • Seek wilderness area expansion	• Prioritize areas for achieving goals and determine specific goals • Adopt new bio control tools for quick action	• Control vs. wilderness • Landscape/regional cooperation • Use forb-eating herbivores?

Table A3-3. Issue/Resource: Bison

Scenario	Current goals: Current actions	Achievable in short-term? Long-term?	Current goals: Revised actions:	Revised goals: Revised actions	Insights, Tradeoffs?
Rather Hot	• Individual producers enrolled in USDA programs • Maintain optimal health and genetically diverse bison population- approximately 1000 animals existing – approximately 17 genetic groups • BADL- help tribes establish their own herds for production & cultural use • Coordination; contingency plans for years when weather affects round ups • Bison EA – conservative stocking rates (protect range) • Round ups opportunity – produce bison • Nutrition on tribal lands		• Less grass • Lower carrying capacity • Surplus bison as numbers are reduced • More round ups • Need a mobile corral system	• Number of animals and unit goals fluctuate • All scenarios: region-wide (not just BADL) bison EA that is participatory and inclusive	• Across scenarios: – Managers need to be adaptive and accommodating as bison already are. – GPS & drone monitoring – Bull exchange program – Culling based on most recent science & needs of recipients • Potential NPS policy changes as needed: – water and feed supplementation – drone use in wilderness

Table A3-3 (continued). Issue/Resource: Bison

Scenario	Current goals: Current actions	Achievable in short-term? Long-term?	Current goals: Revised actions:	Revised goals: Revised actions	Insights, Tradeoffs?
Awfully Dry	Same as above	--	• Increased fence maintenance • Mobile corralling system • Double fencing • Electric hot fence (conditioning) • Supplement water • Develop new water systems - tanks – storage – ponds – natural integration of these • “supplementation” (not allowed in NPS – would need policy change to allow)- Water, Food Medicine • Increased USDA drought program participatory enrollment (more education)	• Number of animals and unit goals fluctuate	• Across scenarios: – Managers need to be adaptive and accommodating as bison already are. – GPS & drone monitoring – Bull exchange program – Culling based on most recent science & needs of recipients • Potential NPS policy changes as needed: – water and feed supplementation – drone use in wilderness

Table A3-3 (continued). Issue/Resource: Bison

Scenario	Current goals: Current actions	Achievable in short-term? Long-term?	Current goals: Revised actions:	Revised goals: Revised actions	Insights, Tradeoffs?
Wet in Bursts	Same as above	• Health and disease concerns and mosquitoes	• Bison may not need to come to water, may need alternative round-up strategies • Distribute more bison to tribes • Mechanism to transfer; tribes ready	• Number of animals and unit goals fluctuate	• Across scenarios: – Managers need to be adaptive and accommodating as bison already are. – GPS & drone monitoring – Bull exchange program – Culling based on most recent science & needs of recipients • Potential NPS policy changes as needed: – drone use in wilderness
The Jungle	Same as above	• Health and disease concerns and mosquitoes	• Bison may not be drawn to water, may need alternative round-up strategies • Higher calving rates and carrying capacity • Distribute more bison to tribes • Mechanism to transfer; tribes ready • Pest and disease monitoring • Drone observation • Develop vaccines for new diseases	• Number of animals and unit goals fluctuate	• Across scenarios: – Managers need to be adaptive and accommodating as bison already are. – GPS & drone monitoring – Bull exchange program – Culling based on most recent science & needs of recipients • Potential NPS policy changes as needed

Table A3-4. Issue/Resource: Black-footed ferret (BFF) habitat

Scenario	Current goals: Current actions	Achievable in short-term? Long-term?	Current goals: Revised actions	Revised goals: Revised actions	Insights, Tradeoffs?
Rather Hot	Goal: Expand current prairie dog colonies (acreage) for BFF Actions: • Continue dusting • Continue monitoring and mapping number of active burrows	Short term – yes Long term – yes • dry conditions favor expansion of prairie dog (PD) and suitable vegetation conditions	Continue ->	Continue ->	• How would plague dynamics change? – maintain geographically separate populations of prairie dogs – ferrets can travel / disperse if plague occurs • Increased pressure from permittees • Expand partnerships (& restoration) to explain PD / BFF / livestock relationships • Ecotourism potential
Awfully Dry	Same as above	Short term – yes Long term – yes PD expansion	Continue ->	Continue ->	• Good scenario for expansion • Increased pressure from permittees b/c of reduced forage • Expand partnerships
Wet in Bursts	Same as above	Short term – No (expansion/ contraction) Long term – No	• Revised grazing management (adaptive management) • Site specific NEPA to increase grazing on temporary basis in wet years • Expand management area for BFF	• Revised grazing management (adaptive management) • Site specific NEPA to increase grazing on temporary basis in wet years • Expand management area for BFF	• Permittees like increased grazing but increased frustration due to changing stocking rates

Table A3-4 (continued). Issue/Resource: Black-footed ferret (BFF) habitat

Scenario	**Current goals: Current actions**	**Achievable in short-term? Long-term?**	**Current goals: Revised actions**	**Revised goals: Revised actions**	**Insights, Tradeoffs?**
The Jungle	Same as above	Short term – No! Long term – No!	• Increase grazing • Expand management area for BFF	• Revised Goal – maintain prairie dog acreage • Revised Action – increase grazing-keep doing what we are doing	• Political environment • Permittees like extra grazing • Pay permittees to graze

Table A3-5. Issue/Resource: Infrastructure, roads, and geohazards

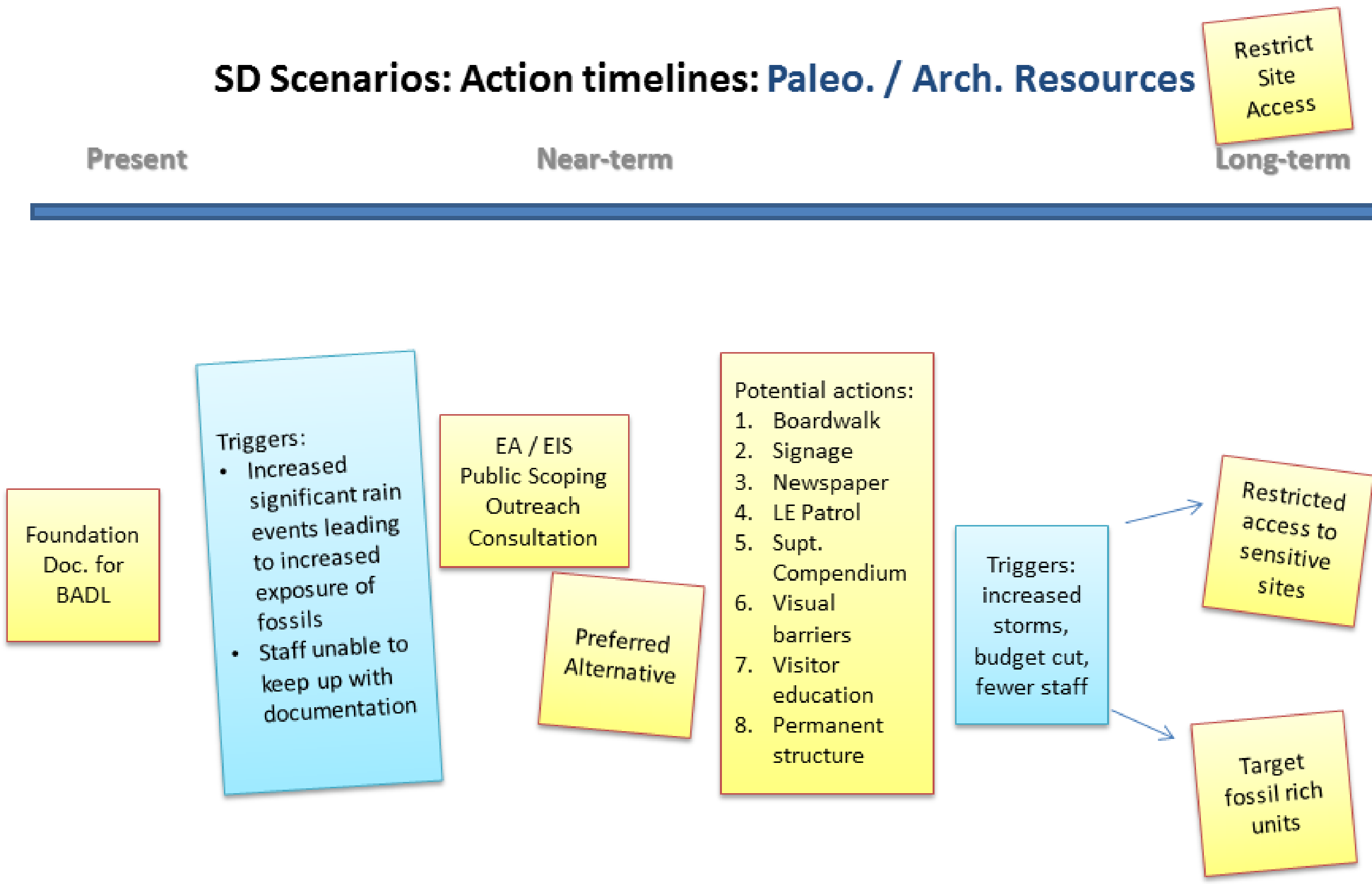
Scenario	Current goals: Current actions	Achievable in short-term? Long-term?	Current goals: Revised actions	Revised goals: Revised actions	Insights, Tradeoffs?
Rather Hot	Goal: Maintain safety and usability Action: Fixing as needed – status quo	Short term – yes Long term – no	• Add culverts • Prioritize actions • Invest in equipment versus contracting • Sustainable transportation options		• More frequent maintenance • Budget pressure • Staffing levels and workloads • Management priorities • Review weight limits (all) • Controlled transportation access • Increased fees = toll road • Controlled seasonal access • Short- and long-term visitor inconveniences • Alternative commercial farm to market roads
Awfully Dry	Same as above	Short term – yes Long term – yes			• Staffing levels and roadwork • See also tradeoffs under rather hot scenario • Management interaction and priorities

Table A3-5 (continued). Issue/Resource: Infrastructure, roads, and geohazards

Scenario	Current goals: Current actions	Achievable in short-term? Long-term?	Current goals: Revised actions	Revised goals: Revised actions	Insights, Tradeoffs?
Wet in Bursts	Same as above	Short term – yes Long term – no	• Add culverts • Prioritize actions • Invest in equipment versus contracting • Sustainable transportation options	• Re-align roads • Re-engineer roads • Inventory infrastructure • Update current drainage systems • Management interaction and priorities	• Management interaction and priorities • See 'Rather Hot' Insights, Tradeoffs
The Jungle	Same as above	Short term – yes Long term – no	• Add culverts • Prioritize actions • Invest in equipment versus contracting • Sustainable transportation options	• Sustainable transportation options • Re-align roads • Re-engineer roads • Inventory infrastructure • Update current drainage systems	• Management interaction and priorities • See 'Rather Hot' Insights, Tradeoffs

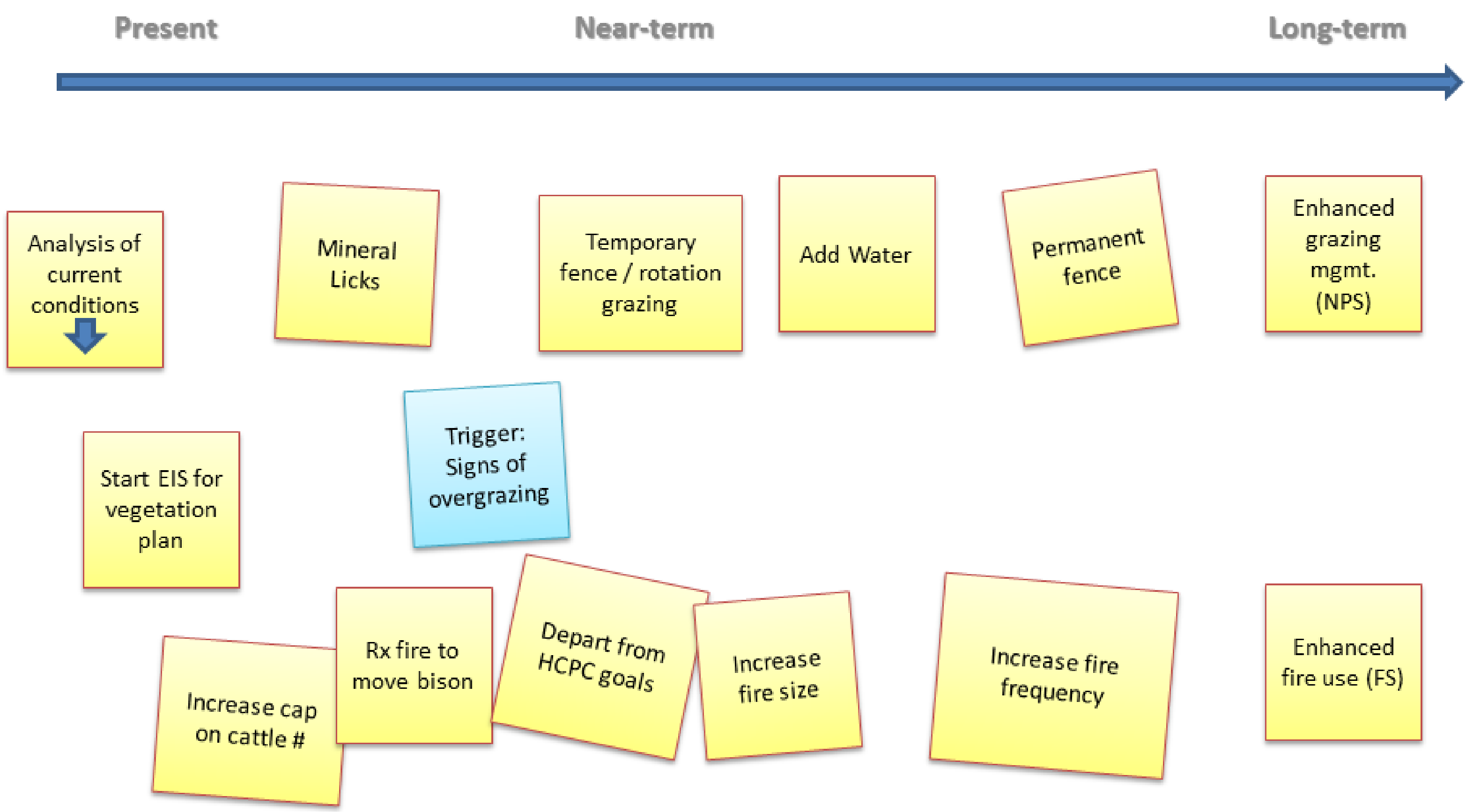
Appendix 4. Action Timelines

Workgroups examined potential future actions, the triggers for these actions, and intermediate steps required to achieve the potential actions in the long term. This exercise does not mean the actions are actually being considered but rather the exercise was used to help managers rehearse for potential difficult decisions in the future.



SD Scenarios: Action timelines: Vegetation

Increase management action
- Fire(FS)
- Grazing (NPS)



SD Scenarios: Action timelines: Bison

Present — **Near-term** — **Long-term**

- Monitor White river flow trends
- Pinnacles weather station precipitation & temp trends
- To detect trends across scenarios

Triggers:
- Bison coming up to water early (April) and for longer
- Larger numbers (e.g. 50%)
- Water quality decrease due to evaporation

Triggers:
- Decreased water quality
- Increased runoff
- Arsenic
- Increased fecal contaminants and dissolved solids

Trigger:
Wildlife trave
greater dista

Triggers:
Five year trends:
- Decreased Sage Creek flow
- Decreased precipitation

Trigger:
- Increase bison (50%) congregating around dam
- Earlier season (April)

Develop: – water collection (e.g. rain water runoff built into swales or from springs) - Monitor water and bison use

Assessing existing dams – repair (Army Corps)

Partnerships
- Strengthen them / create new
- Easements across private & use lands
- Tribes and producers
- ITBC & NGO's

Assess & cap old wells

W. River Limon – Jones pipeline

Interagency Agreements to do the work (e.g. Pine Ridge road crew) – continually build on relationships with tribes

I.D. sites

Tribal College participation – studies & surveys

Funds
- Matching funds

Shared use of equipment

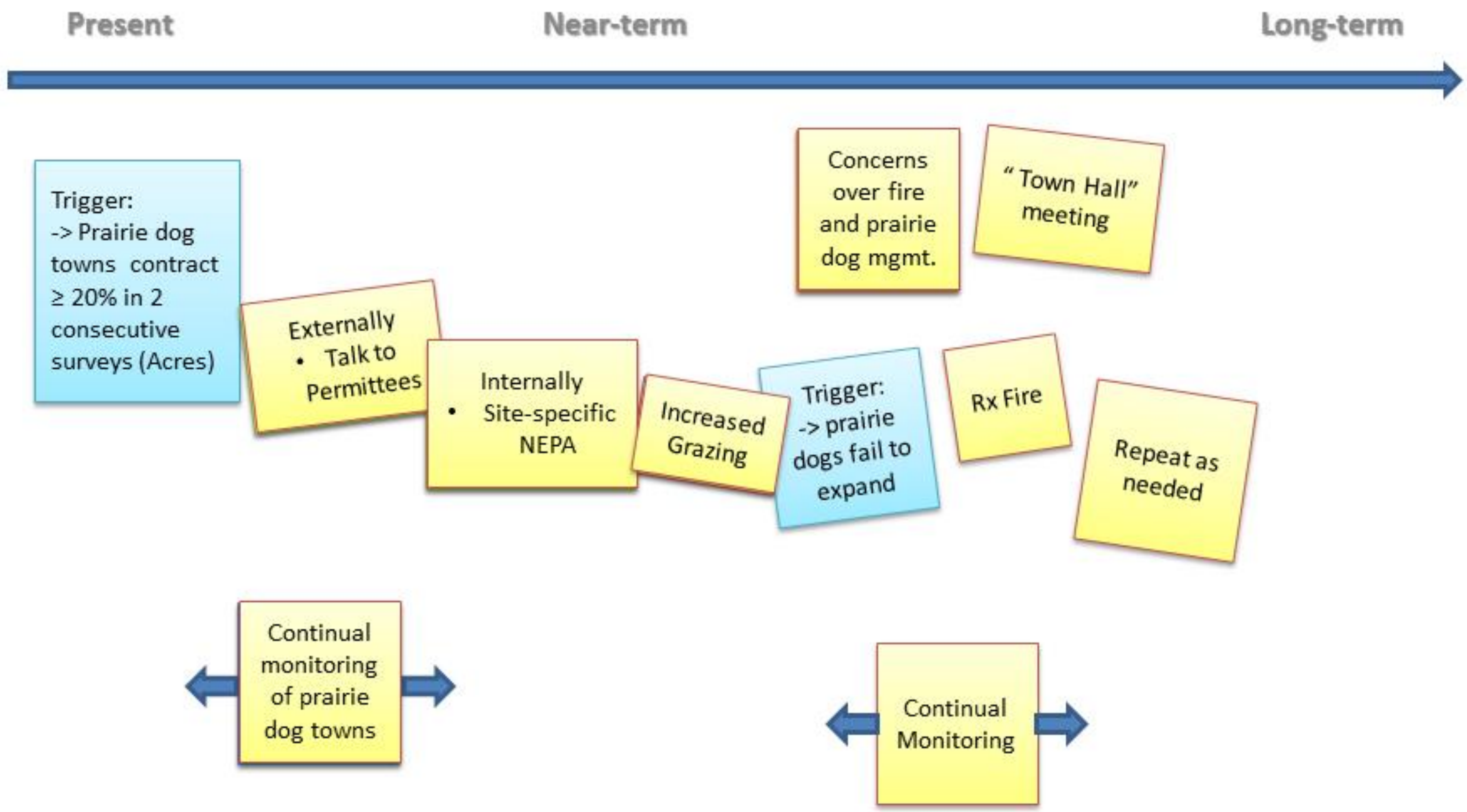
Real Hot & Real Dry
- Supplement water
- Develop new water systems
    - Tanks
    - Storage
    - Ponds

(natural adaption of these)

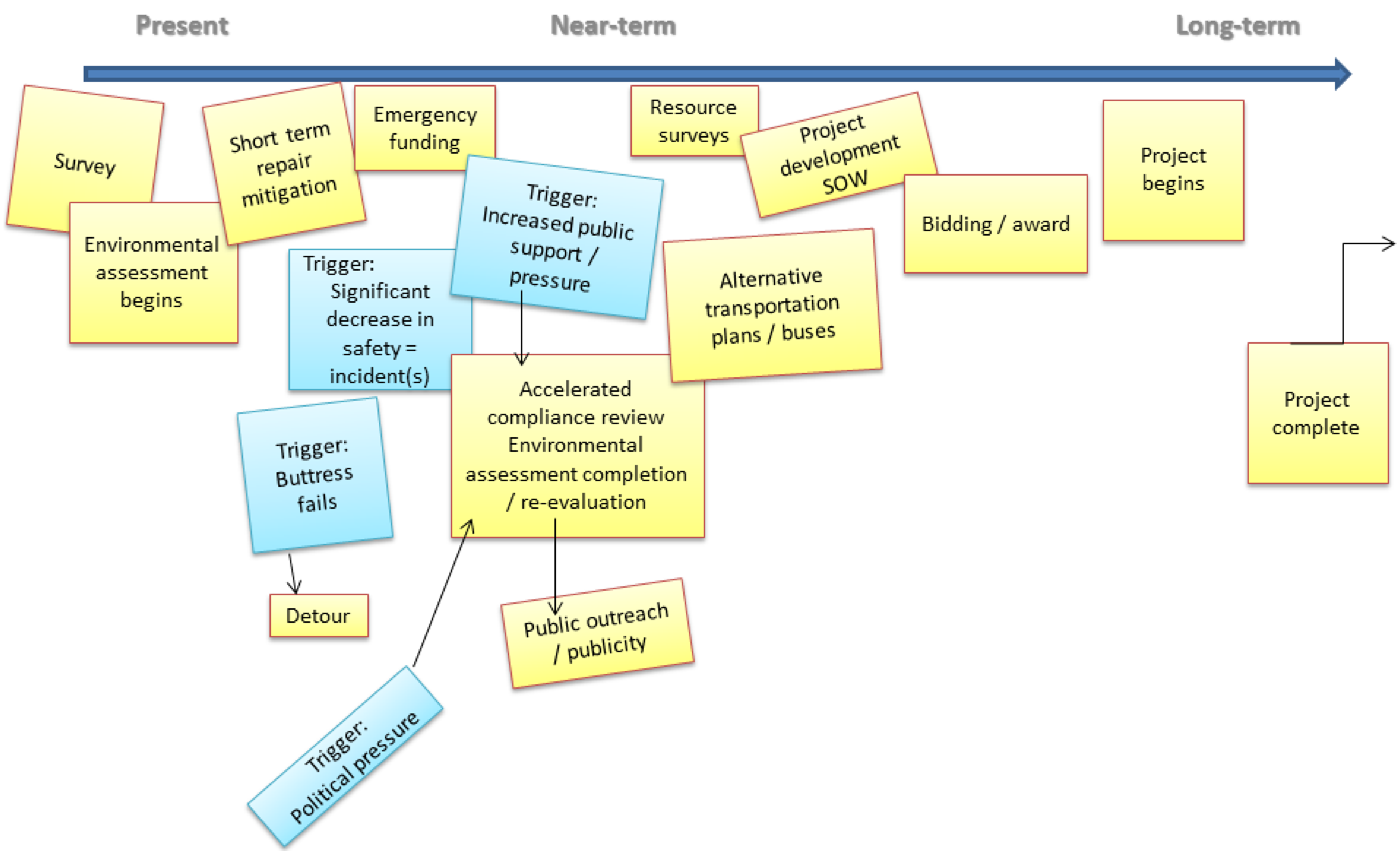
- Topo surveys and design- other prep for putting in permanent water augmentation
- NEPA

Policy Changes
- Based on trends & needs
- Washington Office (direction from)
- Also at tribal level

SD Scenarios: Action Timelines: Black-Footed Ferret



SD Scenarios: Action timelines: Infrastructure



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NPS 909/133937, August 2016

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